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Public works DEPARTMENT.

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Not to be folded or roughly handled

Proceedings of the Madras Government, Public Works Department, 4th May 1871.

Read the following papers :—

No. 56.

No. 71. *Note by the Chief Engineer for Irrigation.*

IN G. O. of the 12th May 1870, No. 1,236, the preparation of the designs and estimates for the Perryaur Project head works was entrusted to Captain Pennycuick, who was at the time about to proceed to England on account of his health, and this Officer has transmitted a Report, dated 14th November 1870, together with estimates amounting to Rupees 16 lacs, tables, and plans illustrating this part of the project. My examination of the papers has unfortunately been much delayed owing to the plans having taken nearly two months to get to Chetterpore, and back to Madras, by banghy.

2. Captain Pennycuick has gone into the subject in a very careful manner, but he has unfortunately not acted upon the decision which was come to with regard to the way in which the freshes in the Perryaur were to be passed down the river, during the construction of the embankment, consequently much of the time which this Officer has devoted to the preparation of the estimates and to detailed calculations, has been thrown away. After the construction of a culvert under the bund had been fully discussed and considered, as one means of providing for the discharge of the water, it was decided that a tunnel through the hill spur, forming the right abutment of the bund, would be the best and most economical arrangement, taking into account the waterway required for avoiding risk of accident to the embankment while under construction. The area of waterway to be allowed was somewhat under 2,000 square feet, 1,666 square feet being that required for passing the estimated maximum discharge of 75,000 cubic feet a second, or 10 millions of cubic yards an hour, with a velocity of 45 feet a second. The length of the tunnel was supposed to be about 330 yards, and its cost about 7 lacs of rupees. The circumstances which induced Captain Pennycuick to design and estimate for a culvert are given in paragraphs 41 to 48 of his report, and the considerations which led to the particular dimensions he has selected are contained in paragraphs 49 to 58; it will be seen that he has proposed to carry out the work in an entirely different manner to that intended in the instructions furnished to him; for, whereas in these the whole of the water was to be passed through the tunnel, and the bund was to be thrown entirely across the river after the completion of the tunnel, Captain Pennycuick proposes to leave a gap in the first instance, and to arrange to close this, after the flanks of the bund have been thrown up, to a height of 150 feet, or a little more, in 60 days (paragraph 57). Moreover, instead of a tunnel, the length of which was to be in excess by 12 feet of the width or thickness of the bund, the culvert has been designed with a length of 658 instead of 990 feet, and this alteration, together with the reduction of the waterway from 2,000 to 649 square feet, has diminished the cost from rough estimate of 7 lacs for a tunnel to the amount, Rupees 2,70,000, allowed by Captain Pennycuick for a culvert. Whatever alternative arrangements this Officer might have himself thought proper to advocate, his first duty was to design and estimate for the works in accordance with his instructions; any suggestions he

	RS.
Culvert	2,15,753
Tools and Plant	30,000
Sundries	24,247
	2,70,000

might have added would have received every attention. As it is, after waiting for many months, some of the information expected has not been furnished, but, in lieu of it, something which was not wanted has been given.

3. It will be noticed that, per square foot of waterway of culvert of two-thirds the length of that of the tunnel, the cost would be Rupees 416, equivalent, for the greater length, to 624 Rupees; that of the tunnel would be Rupees 350 per square foot.

4. Highly valuable as is Portland cement, it seems to me that there are risks which Captain Pennycuick has hardly taken into account. It is a material which must be kept perfectly dry; its quality varies considerably; it might or it might not do to use a concrete containing only one-ninth of its bulk of cement, and, lastly, the construction of piers and arches in this material would require some practical experience before it would be safe to introduce it at a great work of this kind.

5. Captain Pennycuick's proposals to use the surplus water for the purpose of raising a supply to a level which will admit of silting being carried on for the upper part of the bund are worthy of consideration. In Estimate No. IX. he gives the cost of the machinery required for raising $2\frac{1}{2} + 2\frac{1}{2} + 1\frac{1}{4} = 6\frac{1}{4}$ cubic feet a second as 50,000 Rupees, but it may be noticed that the allowance of piping seems to be much in excess of what would be necessary. Mr. R. Smith will be able to determine approximately, from the information given, what sum would be needed on this account. In Estimate I. the cost of the silting channels is entered at 44,000 Rupees in addition to the machinery already referred to; it may be noticed that of the Rupees 11,441, allowed for Portland cement concrete for the dams at the heads of the silting channels, only from one-third to three-eighths would be required for rubble masonry, a material quite suitable for the purpose; the rates for the earth-works also, *vide* Data V., are probably much higher than will be required.

6. The arrangements at the water-shed, referred to in paragraphs 115 to 118 of the Report, would not do at all. The maximum quantity of water required for irrigation in Madura will be about 1,955 cubic feet a second, whereas Captain Pennycuick would send into the Surulyaur 1,103,000 cubic yards an hour, or $8,272\frac{1}{2}$ cubic feet a second, and this would, first, swamp the country; secondly, occasion a great waste of water; thirdly, leave the canals in Madura without any adequate supply during a great part of the irrigation season; there must be no waste except in extraordinary freshes in the Perryaur, and then the surplus should go down the Perryaur, and not across the water-shed. The regulation at the water-shed should be complete, and the water required, and no more, should be passed through the sluices at that point. The arrangements required for the utilization of nearly the whole supply of the upper part of the Perryaur have been sketched out in the note above referred to. Mr. R. Smith has since stated that he thinks the requisite amount of storage can be secured at a lower level by tunnelling under the water-shed instead of cutting through it, and thus making the lake water for some depth below 155,* the intended sill of the cutting, available, and if this can be economically accomplished the alteration will be advantageous. The arrangements are being worked out in detail.

Vide paragraph 12 of Note in G. O., 9th November 1870, No. 2,680.

* Captain Pennycuick has taken 157 in his Report, paragraph 61.

7. Captain Pennycuick's data have been carefully prepared, but the rates therefrom deduced will admit of considerable reduction. It will not be necessary to pay coolies 8 Annas a day; when they are sick it will suffice to give them their rations, and it would be a premium on idleness to pay them under such circumstances 4 Annas a day; the per-centage of sick, namely, 120 out of 1,120, may be allowed to stand, though I hope it will be considerably less. The cost of silting is, exclusive of that of the channels and machinery, put at 1 Rupee for 12 cubic yards; 20 cubic yards the rupee would be a safe and moderate estimate, and the reduction in the rate of cooly hire would make it approximate to this.

No. I.

8. In connection with the proposition, which I made in October last, for increasing the capacity of the lake at the Perryaur and making it the storage reservoir, I have received from Captain Pennycuick a demi-official memorandum, dated 30th December 1870, pointing out what he deems the objections to such a modification. Some of these objections have more or less force, but his estimate of the expense of adding 39 feet to the depth of water appears to me based on rates which are quite inadmissible. In the first place, if water be artificially raised for silting it would add not very greatly to the cost to lift it some 40 or 50 feet higher, or even more, seeing that the power, surplus water, costs nothing. In the next place the rates for earthwork, executed by means other than silting streams, might, if the soil were carried on coolies' heads, mount up as supposed by this Officer; but then no one would dream of so carrying it, and the cost per cubic yard with a tram would be no more, or but little more, at the higher than at the lower level, seeing that in each case the trams would be laid at a gradient, and start from above the level of delivery. Captain Pennycuick has overlooked the whole object of raising the lake surface, which is the securing of storage sufficient for the land to be irrigated. A certain amount of storage will be necessary; what that amount should be will be worked out by Mr. R. Smith more carefully than was done by me in the rough sketch of October last, but, whatever it may be, it is essential to the success of the project. It will be provided on a low level if possible, but, if this be not practicable, it must be obtained at a high level. Captain Pennycuick's memorandum will be found appended to his report.

9. I beg to recommend that these papers, with the plans received with the report, be transmitted to Mr. R. Smith, who will find much of value in them, though much of the detail is inapplicable to the circumstances of the project as now ascertained.

10. Captain Pennycuick has forwarded a bill for £41-18-0, being Mr. Stanford's charge for copying and mounting the plans, and he has also paid £0-12-6 for having the report copied. He mentions likewise that he was put to some expense in visiting Mr. Stanford's office for the purpose of supervising the plans. Had Captain Pennycuick carried out his instructions, it might have been proper to acknowledge his services by a considerable payment on account of the time devoted by him to this work; as it is I would recommend that he be paid

	£	s.	d.
The amount of Mr. Stanford's bill	41	18	0
Do. of charge for copying report	0	12	6
For travelling expenses	7	9	6
	50	0	0

Plans Nos. 5, 6, and 7 are useless; all the rest will be of value, although some of them will require modification.

FORT SAINT GEORGE, (Signed) J. MULLINS, Major, R.E.,
28th February 1871. *Chief Enineer for Irriation.*

From Captain J. PENNYCUICK, R.E., Executive Engineer on special duty, to the Chief Engineer for Irrigation, Madras, dated Hampton Court Palace, Middlesex, England, 14th November 1870.

I HAVE the honour to forward, herewith, the plans and estimates of the head works of the project for the diversion of the Perryaur, entrusted to me by O. G., No. 1,236, of the 12th May 1870, together with an explanatory report.

2. It was impossible for me to send these papers sooner, as my health has been so uncertain since my departure from Madras that I have not been able to work regularly until within the last few weeks, and you will readily understand that the amount of calculation to be gone through has been considerable.

3. I have endeavoured to make the report as complete as possible, so as to avoid any necessity for reference to former papers upon the same subject.

4. I enclose Messrs. Stanford and Co.'s account,* amounting to £41-18-0, for copying the plans; I have also paid the sum of £0-12-6 for the copying of my report. In addition to this I have been put to some charge in the matter of travelling expenses, as the copying of the plans had to be done in London, and I have had to visit Messrs. Stanford and Co.'s office frequently, in order to superintend them; but I am unable to state exactly what this expense has been, as the journeys in question have been so mixed up with those made on my own affairs that I cannot separate them.

* Paid by me.

5. I shall be glad to be informed of any orders that may be passed by the Madras Government in connection with this project.

Report on Project for the diversion of the Perryaur.

THE project for which plans and estimates are now forwarded, is for the diversion of the Perryaur river from its present westward course into the valley of the Vigay, for the irrigation of part of the Madura District.

2. The present state of the district cannot be better described than in the words of Captain Ryves.†

† Introduction to Report on Perryaur Project, 7th August 1867.

"The principal division of the Madura District, consisting of the three Talooks of Madura, Meyloor, and Tirumungalum, is a strip of country running north and south; its eastern boundary marching with the adjoining Zemindary estates of Shevagunga and Ramnad, and on the west separated from the Dindigul division of the district by the mountains and jungle which extend almost continuously, from Nuttam on the north to Strivilliputur on the south, where they run into the general range of the Western Ghauts, which here separate British territory from the Travancore country.

"Its area, excluding uninhabited mountain and jungle, is about 1,200 square miles, with a population of very nearly half a million.

"The Vigay river, passing through the only opening in the hills which form the western boundary, flows across the strip, the length of its course within the limits above defined being about 33 miles. In this length several river channels are taken off, most of them to fill tanks during the short and uncertain period of Vigay freshes. The principal channels are the Vadakurry, the Tenkurry, the Nellayoor, and the Madacolum.

"Vada," north.
"Ten," south.
"Kurry," bank.

"The two first have the advantage of anicuts across the river at their heads, the other two as well as all the other channels, are supplied by means of temporary spurs (made of grass and sand "corumboos") run out into the river. The numerous tanks supplied by the channels were many of them first-class reservoirs originally, but are now so silted up as not to be capable of storing much more than half the quantity of water they were designed to hold; they occupy a great deal of valuable land, and, in the attempt to get as much water as they require, the ryots of one tank frequently cause injury to their neighbours above them by damming up their escape calingulahs and flooding land by the extended water-spread.

"The tanks having become shallow in proportion to the area of the water-spread, there is enormous waste of water by evaporation. I calculate that this waste amounts to at least 30 per cent. of the water stored.

"The character of the Vigay makes the tank system essential. For some reason or other the quantity of water received into the channel of the river bears a very small proportion to the rain-fall on its catchment basin; the average annual rain-fall at Pereacolum and Madura is 32 and 41 inches respectively. In the Cumbum valley (where no register has been kept) it is at least as much* as at Pereacolum; in the Wursanaad valley it is probably less. Taking it at only 33 inches over the whole catchment basin above the Peranny, it would amount to 3,600 millions of cubic yards per annum, and supposing that only one-third of this found its way into the streams and rivers, so as to be available for irrigation, there would be more than enough (with due allowance for the enormous waste on tanks) for three times the extent of paddy crop now raised.

* I should say 40 or 50 per cent. more throughout the valley of the Sooroolly and Teviar.—J.P.

"Yet it is affirmed on good authority that in an average year not a drop of Vigay water reaches the sea; but, I think, this is hardly sufficiently well established to be accepted as the fact. My belief is that sufficient water for more than double the present area of irrigation *does* flow down the Vigay, but that three-fourths of the annual supply passes down the river at three times the rate at which all the channels together can draw off the water from it: so that, if the big freshes could be detained so as to be spread over, say, 60 days, instead of running off at three times the rate in 20 days, it would be found that there would be water enough (if the tanks could contain what it would be necessary to store) for double the present area of rice crops.

"However this may be, there is no doubt as to the main fact that the supply of water obtained from the Vigay is so precarious and scanty that even in good seasons the paddy crop barely covers 22,000 acres annually, although the existing channels and tanks command land enough, and have sufficient hydraulic capacity

B

for the irrigation of fully double that extent of crop if only a sufficient supply of water, delivered at a regular moderate rate, be ensured.

"This Vigay irrigation is situated in the Madura Talook, the middle one of the three named above. In the Meyloor Talook there is but one river, and that but a small stream, at its northern extremity, under which a small extent of land receives a good and certain supply. All the rest of this talook is dependent for irrigation on the local surface drainage, stored in small shallow tanks, the majority of them being mere ponds. Situated, as all the land of this talook is, within a few miles of the water-shed, there are no well-defined streams; the Allighiny hills form a dyke, turning all the hill streams to the north and south round the flanks of the talook.

"The north-east monsoon, from which this talook receives what rain it *does* get, is very uncertain so far south and inland, and the mountains to the west of it (the streams from which as above shown do not flow through this talook) no doubt draw away from it a considerable proportion of the rain cloud which may have travelled so far.

"Under these circumstances it is not surprising that agricultural operations are but seldom rewarded by a good crop. If the ryot is so fortunate as not to find the ground as hard as brick at the ploughing season, the chances are that rain necessary to bring the crops to maturity will not fall at the expected time.

"And the cultivation of wet crops is hardly a less precarious business, failure being attended with greater loss, and success attained generally at much expense of labour and money on raising water from wells and pools.

"Almost every alternate season is one of scarcity in this talook, and when an exceptionally dry year occurs there is severe distress, and the population is thinned by death and emigration. In 1861-62, and again last year,* it suffered severely in this way.

* Written in 1867.—J. P.

"If the water-supply in the Vigay were sufficient, half of Meyloor could be irrigated from it."

3. The idea of increasing the water-supply of the Vigay, by turning into it some of the streams which now flow through the hills to the Western Coast, is a very old one, and more than one attempt has been made to give it practical shape.

4. There are in existence the remains of an old dam across the Sairveyellar one of the minor tributaries of the Perryaur, which appears to have been actually in operation at some former date, and in 1838 an attempt was made to construct a similar dam across a somewhat larger stream, the Chinna Mollyaur, by which the Sairveyellar joins the Perryaur. Considerable progress was made with this work, the remains of which are still clearly visible, but for some reason or other it was abandoned, and no attempt has since been made to resume it.

See Plan No. 1.

5. So long ago as 1808, a proposal was made for the diversion of the Perryaur itself, but does not appear to have received very much consideration, and although the idea has been taken up from time to time since that date, it is only within the last few years that it has been seriously considered with a view to active operations.

Proceedings of the Madras Government, Public Works Department,
4th May 1871.

6. In 1867 Captain Ryves submitted a detailed project, with plans and estimates, for the diversion of the Perryaur into the valley of the Sooroolly, a tributary of the Vigay, and for the distribution of the water-supply thus obtained in the three talooks of Madura, Tirumungalum, and Meyloor.

O. G., No. 3,521, 14th November 1867.

7. It was found, however, that the information at Captain Ryves' command was defective on some important points, and it became necessary to make further investigations into the nature of the country and the circumstances under which the work would have to be carried out.

8. These investigations have been actively carried on during the last two years, and their result is embodied in the papers now submitted to Government. Circumstances appear to require some modifications in the details of the arrangements proposed by Captain Ryves, but in essential points the project remains the same as when first submitted by him.

9. An examination of the map will show that the project consists of two distinct parts, entirely independent of one another in an engineering point of view, though connected financially, namely, the works for diverting the course of the stream and those for the distribution in the Madura District of the water-supply thus obtained.

10. This report deals only with the first part, or head works. Concerning the latter it is sufficient to remark here, that according to Captain Ryves' calculations, which are fairly borne out by the results of our observations during 1869-70, the water-supply of the Perryaur will be sufficient for the irrigation of 149,000 acres of paddy, and will yield a net revenue of Rupees 5,50,000 per annum.

11. The cost of the head works is now estimated at Rupees 16,00,000, so that even if the distribution works cost as much as Rupees 15,00,000,* the revenue would still be nearly 18 per cent. on the cost of the project.

* They were estimated by Captain Ryves at Rupees 5,58,000 only, but this estimate was very hastily made, and there is no doubt is a good deal under the mark.

12. The Perryaur river rises in the hills which separate the drainage basins of the East and West Coasts of Southern India, and, after flowing for some distance with a course generally from south to north, it turns in about north latitude 9° 30′ to the west.

At the angle formed by this change, of course, it receives the Perya Moollyar, which with its tributary, the Chinna Moollyar, brings down the drainage of a considerable tract of country to the north and east of the main river.

13. Running northwards, from the junction of the Perya Moollyar with the Perryaur, is a nearly straight valley, formed in succession by the streams of the Perya Moollyar, the Chinna Moollyar, the Sairveyellar (a tributary of the latter), and a small water-course falling into the Sairveyellar.

See Plan No. 1.

14. At the head of this valley is a remarkable depression in the water-shed ridge, the lowest point of which is about three miles and a half due north of the nearest point of the Perryaur, and 170 feet above its bed at the mouth of the valley.

It is proposed to turn to account the facilities offered by this depression for throwing the waters of the Perryaur over the water-shed ridge into the valley of the Sooroolly.

15. The total difference of level, about 170 feet, may be overcome either by raising the water of the Perryaur by means of a dam, so that it may pass over the ridge; by cutting through the ridge with a dam merely sufficient to close the present valley of the Perryaur, or by a combination of the two processes, overcoming part of the height by raising the level of the stream and part by cutting through the water-shed ridge.

16. The first and most essential points to be fixed are, the site of the dam for closing the Perryaur valley and the proportions of height to be overcome by dam and cutting respectively; in other words, the height of dam and depth of cutting.

17. As the discharge of the Perryaur when in flood is so great that it would cause dangerous inundations if the whole of its water were thrown into the Sooroolly, it becomes necessary to provide, in connection with the dam, an escape or waste weir, by which the surplus water, beyond that which it is desirable to throw into the Sooroolly, may be passed back into the valley of the Perryaur below the dam; the necessity for the construction of such an escape will have an important influence in determining the choice of a site for the dam.

18. An examination of the ground in neighbourhood of the junction of the Moollyar and Perryaur valleys shows that there are three sites (marked on Plan No. 1 as No. 1, No. 2, and No. 3, respectively,) on which a dam may more or less conveniently be constructed.

19. The uppermost of these, or No. 1 site, was that chosen by Captain Ryves on account mainly of certain facilities supposed to be offered for the construction of an escape by the saddles A and B; but the information at Captain Ryves' command was at that time very defective, and it is probable that he would not have chosen this site had he been better acquainted with the details of the nature of the ground. Concerning this site it is sufficient to remark here that a dam 190 feet high would contain as much earth as one 205 feet high on site No. 2 (involving 15 feet more cutting), while, owing to the configuration of the ground, only about one-half of the whole amount of earthwork could be executed by the silting process (which saves five-sixths of the cost of execution by manual labour) against five-sixths which can be so executed at the lower site.

20. There are other minor objections to No. 1 site, but this one is final.

21. Comparing the other two sites, it appears that a dam at No. 3 will contain about one-tenth less than one of the same height* at No. 2, and that the nature of the bed of the river is in some respects slightly more favourable for the control of the stream during the construction of the dam; the facilities for executing the earthwork by silting are about equal, the balance being, if anything, rather in favour of No. 2.

* Within the limits with which we have to deal.

22. On the other hand, there is at No. 2 a saddle, which may be used for an escape, about 205 feet above the present surface of the river; whereas at No. 3 the

only saddles available for this purpose are at more than 240 feet above the river. The lower site, therefore, involves such a very great expense in lowering one of these saddles to form an escape, or in raising the dam in order to avoid this, as will far more than counterbalance the slight advantage offered by the diminished quantity of earth required for a given height of dam.

23. It thus appears that the site marked No. 2 (with the saddle C for an escape) is the most favourable that can be found for the dam.

24. If any given level be assumed for the sill of the cutting through the water-shed, (or what comes to the same thing, for the ordinary surface level of the lake, formed by damming up the river,) the height of the crest of the escape will depend upon the breadth and discharging capacity of the cutting, the area of the lake, and the limit which it may seem advisable to fix as a minimum to be reached by the discharge of the river before any water is allowed to flow to waste over the escape.

25. Again, the level of the escape crest being determined, the height of the crest of the dam above it will depend on the width of the escape, the area of the lake, the discharge of the river during a great flood (which together will determine the maximum level to which the lake will rise), and the clear height which may be considered necessary to allow to the dam above the highest surface level of the lake.

26. It is a fortunate circumstance that, during last year, a flood occurred which there is clear evidence, from the state of the river banks, was greater than any which had passed down for many years. The levels, velocities, and discharges of the river were constantly noted during the whole progress of this flood, and we are thus in a position to form a very good idea of the maximum effort to which our works are likely to be exposed, without the necessisty of using an imaginary table of discharges based upon a certain rate of rain-full discharged by the river for a given time.

See Tables I., V., and VI.

27. The principles on which the relative heights of the sill of cutting, crest of escape, and top of dam have been calculated, are—

See Table IV.

1st.—That no water should pass over the escape until the discharge of the river exceeds an " ordinary big fresh."

See Table V.

2nd.—That the maximum discharge of the cutting during an excessive flood should not greatly exceed one million cubic yards an hour (7,500 cubic feet a second).

3rd.—That the top of the dam should be 15 feet clear above the highest flood level of the lake.

28. If any level be assumed for the sill of the cutting, those of the crest of escape and top of dam will become a matter of calculation, depending on the widths of the cutting and escape and area of the lake, and it is obvious that these

elements are susceptible of an almost infinite number of combinations ; the levels recommended by Captain Ryves were—

Sill of cutting	... ...	129 feet above datum.*
Breadth of cutting	...	40 feet.
Crest of escape	... ...	146 feet above datum.
Top of dam	... ...	166 feet above datum.

Length of escape about 600 feet.

* The datum level of these surveys is the top of a rock in the middle of the river at No. 1 site, and very fairly represented the mean summer level of the river surface at that point and for nearly a mile lower down.

29. Captain Ryves contemplated executing the whole of the earthwork in the ordinary way by manual labour, but the introduction of the "silting process" by Mr. McIvor, has so diminished the cost of this work as to render it advisable to raise the dam and effect a corresponding saving in the amount of cutting required.

29. After a large amount of very careful calculation, I have come to the conclusion that the following proportions will be the best :—

Level of cutting sill	...	157	feet above datum.
,, escape crest	...	174	,, ,, ,,
,, top of dam	...	205	,, ,, ,,
Width of cutting at bottom		30	,,
Length of escape ,, ,,		400	,,

30. It does not appear necessary to detail all the calculations by which these results have been arrived at, but I may mention that if all the levels were reduced 5 feet, we should save in the construction of the dam about 150,000 cubic yards of earth, of which 30,000 would be from the part executed by silting and 120,000 from that executed by manual labour. Against this there would be an additional 60,000 cubic yards of rock to be removed for the formation of the escape, and an addition to the cost of the cutting of above Rupees 20,000, besides other minor alterations, the general result being that the whole work would cost about Rupees 45,000 more than the present estimate. There would be no saving of time ; indeed, it is possible that the large amount of blasting required for the escape might render another season's work necessary.

31. On the other hand, if all the levels were raised 5 feet, the additional earthwork required would be about 30,000 cubic yards by silting and 132,000 by manual labour ; the reduction in the quantity of rock to be removed from the escape would be about 44,000 cubic yards, and in the cost of the cutting about Rupees 8,000.

32. If the same rates as those adopted in the present estimate were taken, this alteration would cause no appreciable increase or reduction in the total cost of the works ; but the rates for earthwork would probably be slightly increased, as the earth for executing the upper part of the dam would have to be brought from a greater distance ; the time required for the completion of the work would be probably, though not certainly, increased by a season.

33. It appears then that the level chosen is the most favourable in an economical point of view, and also as regards the time required for carrying out the works, since the time required for executing the dam is about the same as that for forming the escape and cutting. If the levels are raised the dam would probably

take longer, and, if lowered, the escape and cutting would require more time. It is difficult to speak positively on this point, but I doubt whether we could command skilled (or at least semi-skilled) labour enough for the execution of more than 50,000 cubic yards of blasting in each season.

34. All the calculations from which the quantities of work to be done have been deduced are based upon careful and detailed surveys of the ground affected and actual examination of the depth of earth, with the exception of the relative proportions of rock and earth to be removed for forming the escape, which can only be considered as an approximation, circumstances having prevented a detailed examination of the saddle (C) being made before the close of the last season's work at the Perryaur.

35. The depth of earth on this saddle has therefore been assumed, the estimate being based on the depths known to exist on similar saddles in the neighbourhood which have been examined, and enough is known of the nature of the ground on this one to render it tolerably certain that the conditions assumed do not differ greatly from those actually existing, and that if there be any difference it would probably be that the depth of earth is greater than I have supposed.

36. In a memorandum, No. 95, of the 27th April 1870, Major Mullins remarks that should the rock be found at a lower level than I have been led to expect, he should be disposed to reduce the levels by 5 feet. I do not think this would be desirable; the reduction caused by the rock being found at a lower level than that which I have assumed, will at any rate not be great, and will be confined to a small area near the centre of the escape.*

* We know the position of the rock, a short distance east and west of the centre, as it appears in the beds of the water-courses.

Thus, although the actual cost of the escape, whatever may be the level of its crest, may be somewhat less than I have allowed, yet the relative cost of an escape at the 174 feet level and one at 169 feet will remain the same, and the arguments in favour of the higher level will apply equally, whether the rock at the saddle be found at 190 feet (as assumed) or a few feet lower.

37. The length which I have allowed for the escape crest is 400 feet. If it were made shorter there would be a reduction in the cost of the escape, but the dam would have to be made higher (or the escape crest lower) to allow for the increased depth of water which must pass over during a flood. If the escape crest were lengthened, the height of the dam might be *slightly* reduced, but the cost of the escape would be greatly increased.

38. Calculation of the relative cost for various lengths of escape crest shows that the length named, 400 feet, gives the best results.

39. Since the execution of the earthwork of the dam will occupy three or four seasons, it becomes necessary to provide for the discharge of the river during the progress of the work. It would be obviously impossible to pass (at any reasonable cost) the discharge of such a flood as that shown in Tables V. and VI. over the dam by means of syphons or any similar arrangement, and out of the question to allow it to flow over the earthwork.

40. We appear to have to choose between only two alternatives: a culvert underneath the dam, and a tunnel through the hill on one side of it, communicating with the river above and below, by open cuttings.

41. At the time that I left India, the latter course, which was first suggested by Colonel Orr, was believed to be the best, inasmuch as a masonry culvert would require a large amount of skilled labour, of which it was doubtful whether we could command sufficient to complete the culvert within a reasonable time, and would certainly cost much more than a tunnel of the same waterway.

42. Since I have been in England, I have had the opportunity of seeing Portland cement concrete used on a very large scale in marine works, and I am convinced that by the use of this material we shall be able to construct, in perfect safety, a culvert in less time and with the expenditure of far less local labour than would be required for a tunnel of the same capacity.

43. At Douglas, in the Isle of Man, this material is being used for the faces (not merely for backing or filling in) of the sea walls, and parts of the wall which I saw have been exposed for two years to the action of the sea without the very smallest injury being preceptible. The steps of the landing quays are of this concrete, and after having been exposed between high and low water for two years to the full force of the sea, and to all the wear and tear incident to such a position, they are as clear and their edges as sharp as the day they were built.

44. At Port Erin, on the south-western coast of the island, the concrete is exposed to a test still more severe. There it is used in blocks of from 10 to 18 tons weight for filling in, without packing, cement, or arrangement of any kind, the space between piled framings for forming a breakwater; used, in fact, as *pierre perdue.* At this place I saw blocks which had been down between high and low water for two winters, and there was not the smallest sign of erosion or fracture on any of them; in fact, I should have been surprised to see the hardest stone in such a position so little worn.

45. In works of this nature, the concrete is not exposed to precisely the same action as in a culvert with water passing through it at a velocity reaching occasionally to perhaps 60 feet a second, but the whole action of the sea on one of the stormiest parts of the English coast* must expose it in another way to a far greater strain.

* The breakwater at Port Erin runs across part of the chord of a nearly semi-circular bay completely open to the south-west. Its main object is to afford a place of refuge to the numerous fishing-boats which ply about the island.

46. Mr. Powell, the Engineer to the Isle of Man Works, to whom I am indebted for much valuable information on this point, agrees with me that there would not be the slightest risk in using the Portland cement concrete for a culvert under such conditions as we have to deal with, and the question of safety being conceded, on other points the superiority of a concrete culvert over a tunnel is undeniable.

47. As to cost: at the rate of 10 Rupees per cubic yard for excavation in rock, the tunnel would cost a little less than a culvert of the same length and area of waterway; but the culvert, as will be explained hereafter,* need only be made to run under about two-thirds of the whole length of the dam, whereas the tunnel, with the open cuttings at its two ends, must be made sufficiently long to clear both faces of the dam when complete. This would cause the total cost of the tunnel to be considerably greater than that of a culvert of the same discharging power;

* Paragraph 60.

its construction would occupy certainly two and possibly three seasons, while the culvert could be easily completed in one, and, lastly, almost the whole cost of the tunnel will be expended in local labour, and chiefly in blasting, of which we have already a large amount to execute for the escape and cutting, whereas seventeen-eighteenths of the cost of the culvert* is for the price of the cement, the amount of local labour required being very trifling. This latter point is of the utmost importance, seeing how essential it is to reduce the quantity of local labour required as much as possible.

* See table of Data, No. IV.

48. For these reasons I have determined to recommend a culvert of Portland cement concrete, as the best means for passing the stream of the river under the dam during its construction.

49. It is necessary next to consider the dimensions to be given to the culvert.

50. There are two periods at which heavy floods may be looked for, namely, during the south-west monsoon, which may be said to close about the middle of July, and during the north-east monsoon, which may commence any time after the beginning of October and extend to the begining or middle of December. Small freshes may be expected, and great floods are not impossible, throughout the latter half of the year, but freshes of any magnitude will be very rare except during the periods named.

51. The capacity of the culvert must, therefore, be such that the remainder of the bed of the river being closed, a flood cannot rise to within 10 feet of the height to which a dam canbe carried in the period between the close of the south-west monsoon and the commencement of the north-east, or between the close of the latter and the end of the working season in February,† the period in either case being limited to about 60 working days.

† The extreme unhealthiness of the Perryaur country from March to June, renders it absolutely necessary to stop all work during these months. The working season is therefore limited to the eight months from July to February, or about 200 working days, at 25 days per month.

52. It is calculated that if the whole breadth of the river were closed at once, a dam with a top width of 20 feet, and front and rear slopes of 2 and 3 to 1 respectively, could be carried to a height of about 110 feet within the period named. The culvert must, therefore, have a capacity sufficient to prevent a great flood, such as actually occurred in November last, from rising to a height exceeding 100 feet.

53. To effect this the culvert would require a waterway of more than 2,000 square feet, and its execution would take probably two seasons; a tunnel of the same area would require four or five.

54. In order to reduce as much as possible the cost of the culvert and the time required for its execution, I propose to complete the dam on the flanks and over a portion of the bed of the river, before closing the centre of the bed, so as to diminish the length of the dam to be constructed in the limited period above named. This will enable us to carry the dam to a greater height between the two monsoons, and reduce the waterway required for the culvert.

55. The present width of the river bed varies from 116 feet at the upper end of the length covered by the dam to 206 feet at its lower end.‡ At the latter point the stream is very shallow, indeed half its bed is frequently dry even during December.

‡ The greatest width is a little above the lower end of the site, nearly 250 feet, but a good deal of this is taken up by rocks and huge boulders.

56. There would be neither risk nor difficulty in narrowing the aperture to a width of 120 feet, and leaving this space for the stream to flow through freely until the work on both flanks was carried up to its full height.

57. Over this space of 120 feet in length a dam with a top thickness of 20 feet could be carried in 60 days to a height of 150 feet, or perhaps a little more. The area of the culvert must, therefore, be such as to prevent a flood from rising to above 140 feet.

58. This will be effected* by giving to the culvert the dimensions which are shown on the plans, namely, three arches each of 9 feet span, and 20½ feet height up to the springing of the arches—total area of waterway 649 square feet.

* See Table VI.

59. The culvert might possibly be made smaller, as it is not likely that such a flood as I have anticipated will occur during the particular year in which the central portion of the dam is executed; still we know that such a flood has occurred and may occur again, and it seems best to provide against the greatest risk which may reasonably be considered possible.

60. The dam will have a front slope of 3 to 1, with a top width varying from 40 feet in the centre to 20 feet at each end; but, in order to reduce as much as possible the cost of the culvert, I propose to make it of sufficient length to carry a dam with a rear slope of 7 to 5 only; * this will leave an opening in the dam above and beyond the lower end of the culvert, which will have to be filled in after the culvert is closed on the completion of the remainder of the dam. There will be no dfficulty in making the rear slope of the dam stand at the inclination stated, and, as the water above the dam can never rise to a higher level than 140 feet so long as the culvert is open, the mass of this portion of the work will be amply sufficient for stability. Indeed the culvert might be made even shorter than I propose, but that the opening in its rear would then be more than we could be sure of being able to fill up in the period between the closing of the culvert and the end of the same working season.

* See Plan No. 7.

61. To repeat the principal dimensions of the various parts of the work:—

Level of top of dam	205 feet above datum.
Crest of escape	174 " " "
Sill of cutting	157 " " "
Top thickness of dam at centre ...	40 feet.
Do. do. at ends ...	20 "
Front or upper slope	2 to 1
Rear or lower do.	3 to 1
Length of escape	400 feet.
Bottom width of cutting	30 feet.

Culvert to consist of three arches, each 9 feet span, $20\frac{1}{2}$ feet high up to springing, and 25 feet to crown of arch; area of waterway 649 square feet, thickness above crown of arch $2\frac{1}{2}$ feet; total height $27\frac{1}{2}$ feet. Thickness of piers 4 feet, of foundations 5 feet, depth of foundations 4 feet. Length of culvert 658 feet.* Sill of culvert to be as near datum level as possible.

* This is somewhat more than the thickness of the dam at this level, as the formation of the river bank requires the culvert to be built somewhat obliquely to the general line of the dam.

62. The main outlines of the scheme being thus decided on, it remains to consider in detail the mode of carrying it out. It will be understood that the time mentioned in this report, as necessary for the completion of the works, is exclusive of that required for the execution of the road to the site of the dam, which is believed to be now in progress, and which must be completed before the actual execution of the works at the Perryaur can be commenced.† The working season, as already remarked, occupies from the beginning of July to the end of February.

† It would be convenient that the machinery required should be transported to the river bank at the end of the season before that in which the works are to be commenced, as the roads are likely to be in better condition for the transport of heavy loads in January or February than in July.

63. The first thing to be done is the commencement of the "silting channels" from the site of the dam to the Chinna Moollyar by the right bank of the Perryaur, and to the Arinashi stream by the left bank (see Plans 1 and 2); at the same time the excavation for the foundations of the culvert should be commenced, as well as the blasting away of the escape saddle.

64. As soon as the silting channel on the right bank reaches the Palgatchemadu stream, which should be by the middle of August at latest, the distance by the channel being only about 3,000 yards and the ground easy, the water of this small stream will be turned into it, so as to give a power for working the turbines‡ by which I propose to drive the machinery for the manufacture of concrete.

‡ These turbines will be afterwards required for raising water for silting; see paragraphs 90-92.

65. The Palgatchemadu stream has a drainage of about one square mile, and from July to November its discharge is not likely to be less than 3 cubic feet per second. The available fall from the silting channel is about 90 feet, and as a turbine does a duty of over 70 per cent., the available power at command for working the concrete machinery will be $\frac{7}{10} \times \frac{3 \times 60 \times 62\frac{1}{2} \times 90}{33,000} = 21\frac{1}{2}$ horse power nearly,‖ the power actually required being not more than 16.

‖ Which may be more than doubled at a very trifling cost, by storing water during the night for use during the day.

66. The concrete-making machine consists essentially of a hollow cylinder about 6 feet long and $3\frac{1}{2}$ feet in diameter, turning on its axis, which slopes from the horizontal at about 1 in 8. In the inside of this cylinder are four blades running its whole length and crossing (in section) about half the breadth of a chord of 125 degrees.

67. The materials for making the concrete, are inserted at the upper end of the cylinder, and are thoroughly mixed by being turned over and over by the blades as it revolves. At the same time by the longitudinal slope of the cylinder they gradually slide forward until they issue in a completely mixed state at its lower end, where they may be received at once into the moulds or frames for supporting the concrete until it is fully set.

68. The quantity which one machine will turn out is about 240 cubic feet in an hour, or 2,160 cubic feet in a day of nine hours. I propose to use two machines, which will enable us to execute all the concrete required for the culvert in less than 100 working days.

69. Wooden moulds or framing will of course be necessary for the piers and centering, which may be easily and cheaply constructed with bamboos, for the arches. The greater part of the culvert will be on the bank, quite clear of the river bed. A few feet at the lower end may have to run into the river, but the stream here is so shallow that in moderately dry weather there will be no difficulty in setting up the framing.

70. In order to avoid the labour of carrying the concrete to any great distance from the machines, I should propose to mount these on trucks, running on rails laid along the completed portion of the culvert walls, so that the machinery could be run forward as the work progressed.

71. The proportions of materials required for the concrete are given in the Table of Data No. IV. The sand and shingle can be obtained in unlimited quantities from the bed of the river, a short distance above the site of the dam, to which they will be brought in boats.

72. The stone will be obtained from that removed for the formation of the escape, and will be broken up by a machine driven by the same turbine as works the concrete machines.

73. The stone-breaking machine consists essentially of two powerful steel jaws, one fixed and nearly vertical, the other movable in a vertical plane on a pivot at its lower end. This jaw is moved by an eccentric, at each revolution of which it advances and recedes one-fourth of an inch. The distance apart of the jaws at the top is about three times that at the bottom. A stone being dropped in at the top slips down until it is stopped by the converging faces of the jaws; it is slightly broken by the next forward movement of the movable jaw, and the pieces slide down until again stopped, and so on until they are small enough to pass out at the bottom opening, the width of which is regulated according to the size to which the fragments are to be broken.

74. I have seen both these machines at work, and can testify to the simplicity of their construction, and to the ease and completeness with which they work.

75. Towards the end of the season, when the water in the hill streams begins to diminish, the construction of the dams for turning the Chinna Moollyar and Arinashi streams into the silting channels, will be commenced. It will be well here to give a brief outline of the "silting process" for executing earthwork, and of the extent to which it is proposed to adopt it at the Perryaur.

76. The essential requisites for carrying out this process are, a supply of earth at such a height above the place where it is to be used in a dam or embankment, as to allow it to be brought to that place at a gradient which should not be less than about 1 in 20, but may be as much more as possible, and a supply of water in such a position as to enable it to be passed through the earth quarries.

77. These requisites being obtainable, a small channel is made through the earth quarries to the site of the dam or embankment, and the water turned into it; the earth along the bank of the channel is loosened so as to fall into the water, by which it is carried down to the embankment in the form of thick mud. On

arriving at the embankment, this mud being spread over a large surface the earth sinks to the bottom, and the water is drained off nearly pure, leaving the earth behind in the form of very fine silt, which in a short time hardens into a mass firmer and more homogeneous than could be obtained from any amount of manual labour.

78. The water thus does all the transport of the earth, and greatly aids in its excavation, the only labour required being that of a few men for watching the channels,* keeping them clear of stones, etc., (the channels themselves are mere notches, of which a cooly can cut a yard in a few minutes,) for making and keeping up a small bank by which the water is kept on the top of the main embankment until the earth is deposited, and a certain number for loosening the earth so as to allow it to fall into the silting channels. For this latter purpose I have allowed† one man for every 10 cubic yards. Where the soil is good a cooly would probably do 15 or 16 cubic yards in a day of nine hours, but about the Perryaur the earth, even at the best places, is a good deal mixed with roots and stones, and I do not consider that it would be safe to allow a greater quantity than that named.

* And at the Perryaur, for watching the main channels which bring the water to the site of the works. This is necessary to prevent injury to these channels from rain and other causes, above all from the elephants which infest this part of the country.

† See Table of Data No. II.

79. An examination of the plan (No. 4) and of the Tables of Quantities, Nos. I., II., and III., will show that the supply of earth in such a position as to fulfil the conditions required is not quite sufficient for the construction of the whole dam.

80. Up to 70 feet above datum all the earthwork may be executed by the silting. Above that level sufficient earth could be obtained to complete the dam up to about 150 feet; but as a certain amount of this can be brought to the dam at a much higher level than 150 feet, some indeed to the very top of the dam, I prefer to distribute the earth available for silting along the full height of the work (above 70 feet), executing a certain portion by silting, and a certain portion by manual labour, rather than to execute the whole of the lower part by the former process and of the upper part by hand. Moreover, this course does away with the necessity of puddling the face of the dam, which is not necessary where the silting process is employed, but would be required wherever the whole thickness of the dam was executed by manual labour.

81. In comparing Table of Quantities No. III. with Nos. I and II., it must be borne in mind that earth shown therein as available for any given level may be used at a lower one but not at a higher.

82. We have next to consider the possibility of obtaining water for transporting the earth which is found to be available for our purpose.

83. On the right bank of the Perryaur, the only streams of any considerable size within a reasonable distance of the site of the dam are the Chinna Moollyar, which joins the Perryaur about a mile and a quarter above the site, and the Nellecumputty stream, which joins it about four miles below. The latter stream, up to a considerable distance above its junction with the Perryaur, as well as the ground between it

See Plan No. 1.

and the site of the dam, has been carefully surveyed, but the result shows that the facilities offered by it for obtaining a water-supply are greatly inferior to those offered by the Chinna Moollyar. The channel for any given level would be considerably longer and the supply of water very much less. Indeed the greater part of the drainage of the Nellecumputty stream comes from so low a level that the stream itself is quite insignificant at 200 feet above datum. The Chinna Moollyar then is the only stream (on the right bank of the river) that can be made use of for the purpose under consideration.

84. At a level of about 132 feet above datum the Chinna Moollyar is joined by a small tributary, the Sairveyellar, whose valley has a slope much more gentle than that of the Chinna Moollyar itself; if the main silting channel were taken off from the latter above the junction of the two streams, we should require either a high aqueduct to carry the channel over the Sairveyellar (losing at the same time the water, about one-fourth of the whole, which it brings down) or a long channel to turn it.

85. I propose, therefore, to take the silting channel from the Chinna Moollyar just below its junction with the Sairveyellar. The level of the bed of the channel here will be 140 feet above datum; its length to the site of the dam will be 23,000 feet, so that allowing a fall of 1 in 1,000, it will reach the dam at the level of 117 feet.

86. The drainage area of the Chinna Moollyar, at the point where the channel leaves it, is about 12 square miles, or one-twentieth that of the Perryaur at the site of the dam.

87. Taking the discharges of the two streams, as holding the same proportion to one another as their drainage areas, and neglecting as "fresh" in the larger stream all discharges above 500 cubic feet a second, I find from our daily records of discharge during the last season that we can confidently calculate on a supply from the Chinna Moollyar of from 22 to 24 cubic feet per second from July to December, of 18 cubic feet in January, and 6 cubic feet* in February.

* This is less than one-twentieth the discharge of the Perryaur, but the Chinna Moollyar is more dependent on local rain, and the discharge therefore diminishes more rapidly in dry weather. The stream was gauged during the latter part of last season, but the observations were too few to be of much value.

88. These quantities are those which will be actually brought down by the channels; but as the work will only be carried on during nine hours out of the twenty-four, the water brought down during the other fifteen may be stored in small reservoirs, constructed in favourable positions, of which many may be found near the site of the dam, so that the actual amount of water available for silting will be $2\frac{2}{3}$ times that stated in the last paragraph. The cost of these reservoirs will be very slight; provision has been made for them in the estimate,† and one or two favourable sites indicated on the Plan (No. 4), but there are many others equally good.

† No. I.

89. The amount of earth deposited by a given quantity of water depends on the nature of the soil and the gradient of the branch silting channels. As an average, it is believed that about 40 cubic yards of earth per hour, or 360 cubic yards in a day of nine hours, will be deposited by one cubic foot of water per second.

90. The *maximum* quantity which I propose to use directly for silting from one bank is seven cubic feet and a half a second,* and the surplus will be made use of in order to obtain a supply of water for transporting the earth which lies at a higher level than can be commanded by the main channels.

* 20 cubic feet during working hours, which will suffice for the execution of 7,200 cubic yards of earth in a day.

91. This course was first suggested by Lieutenant Greer, who proposed the use of hydraulic rams for the purpose of raising the water required; but after consultation with Messrs. Gwynne and Co., the well-known Hydraulic Engineers, I have come to the conclusion that the best way will be to use force pumps, driven by turbines, the latter being worked by the water brought from the Chinna Moollyar.

92. The machinery provided in the estimate† will be sufficient to raise about 6 cubic feet per second to an *average* height of 90 feet above the level of the main channel, by an expenditure of double that amount in working the turbines. This will give during working hours an available daily supply of $6 \times \frac{24}{9} = 16$ cubic feet per second, if required.

† No. IX. (*f.*)

93. In order to turn the stream of the Chinna Moollyar into the silting channel, I propose to erect a concrete dam of the dimensions shown in Plan No. 3. A dam of this nature appears preferable to one of earth, as although the latter would cost less in construction, it would involve a heavy expense in cutting an escape channel through the bank at the side of the dam, in order to prevent the latter from being swept away by floods two or three times in the course of each season.

94. The head of the channel will be protected by a wing-wall, and the water conveyed to it by a 21-inch pipe, the mouth of which can be partially or entirely closed by a sluice valve if it be required to shut off the water from the channel. The level of the pipe has been fixed so that no water shall pass over the dam until the discharge of the river exceeds 25 cubic feet per minute. The maximum amount which the channel will carry (the depth being 2 feet) is 32·3 cubic feet per second.

95. The channel is shown in section on Plan No. 3. The earth excavated in its formation will of course be thrown on the outside, so as to form an embankment to the outer edge of the channel. This is not shown in the section.

96. In order to avoid the length of line, and consequent extra fall necessary for carrying the channel round the numerous ravines with which the ground is intersected, I propose to carry it across these by means of wooden troughs, supported on bamboo trestles. These can be easily and cheaply made, as materials will be found on the spot.

97. On the left bank of the Perryaur examination of the ground has shown that the only stream which can be made use of for silting is the Arinashi,‡ which joins the Perryaur rather more than four miles above the site of the dam. We have no means of judging accurately what the discharge of this stream may be, as its drainage basin is altogether unsurveyed, and it is too rapid to gauge with such means as were at our disposal last year except in very dry weather. It is, however,

‡ Plan No. 2.

not much smaller than that of the Chinna Moollyar, and would be sufficient for our purpose were it only one-half the amount, the supply of earth on the left bank being less than that on the right, and a much larger proportion of it being below the main silting channel.

98. The same principles have been followed in dealing with this stream as with the Chinna Moollyar. The dimensions of the dam and channel are shown on Plan No. 3. The maximum discharge of the channel will be $24\frac{1}{2}$ cubic feet per second, and no water will pass over the dam until the discharge of the river reaches 22 cubic feet per second.

99. The cost of the silting apparatus has been shown separately in Estimate No. I., in order to enable it to be compared with the amount saved by the use of the silting process. It will be seen that this estimate amounts to Rupees 94,000, and that the use of the silting process enables us to execute for Rupees 1,67,000 an amount of earthwork (2,000,000 cubic yards) which we could certainly not execute by manual labour for less than 800,000. The cost of the apparatus for raising the water is Rupees 50,000, and this enables us to execute by silting for Rupees 1,03,000 (1,232,000 cubic yards) earthwork which are not commanded by the main channels, and which would cost by manual labour Rupees 4,60,000 at least.

100. The completion of the culvert, silting channels, and dams, with all preparations that may be necessary for the commencement of the earthwork, is calculated to occupy the first season, during which also the blasting for the escape will be steadily carried on.

101. At the commencement of the second season a rough-stone dam, 15 feet high, will be thrown across the river from each end of the culvert, and the interstices between the stones silted in so as to make the dams as nearly water-tight as possible. The ordinary stream of the river will then pass through the culvert, and still-water being thus obtained in the rest of the river bed the earthwork from the left bank will be carried out to within 120 feet of the outer edge of the culvert, and to the full thickness of the dam at its base. Above this it will have a front slope of 2 to 1, a rear slope of 3 to 1, and an end slope (towards the river) of 1 to 1.

102. The earthwork on the right bank above the culvert will be carried on in the same way throughout the season.

103. The side slopes of the central opening will be revetted with stone to 55 feet above datum at the upper end, and 45 at the lower, to protect the earthwork from erosion during floods and freshes, which will of course pass over the rough-stone dams. The rear slope of the dam will also be revetted up to 40 feet above datum.

104. It is calculated that during the second season the earthwork may be carried to 110 feet above datum on the left bank, and to 120 feet on the right bank.*

105. During the third season the two flank portions of the dam will be completed to their full height.

106. During the first part of the fourth season the central opening will be closed up to a height of 120 feet.† The dam thus formed to have a top width of 20 feet, a front slope of 2 to 1, and a rear slope of 3 to 1. It is probable

* Plan No. 5.

† Plan No. 6.

that the rough-stone dams across the central opening will have been a good deal damaged by the floods of the two previous seasons, but enough of them will remain to turn the stream through the culvert during nine days out of ten, and thus allow the lower part of the earthwork to be carried out without interruption.

107. It is during this period that there will be the greatest risk of injury to the earthwork by freshes, as a heavy flood occurring during the time occupied in constructing the lower part of the central dam would sweep over and carry away more or less of the work. It is however improbable, though not impossible, that a flood of any great extent should occur in August or September, and the risk is really not very great. At any rate it cannot be avoided, whatever its extent may be.

108. During the latter part of the fourth season the central opening will be filled in to its full width up 120 feet above datum.

109. It may possibly be considered better to increase the height of the dam across the central opening during this period, instead of merely increasing its thickness at the base. In this case it might be raised to 180 feet, keeping the top width at 20 feet. This would of course have the effect of rendering the work still more secure against floods during the next south-west monsoon, but as the height of 150 feet is amply sufficient for this purpose it does not seem of much consequence which course is adopted.

110. During the first part of the fifth season the central opening will be completely closed to its full height and width.*

* Plan No. 7.

111. There will then only remain the opening in rear of the culvert, which will be filled in as soon as the fall of the river at the close of the north-east monsoon enables the culvert to be closed without difficulty.

112. This will probably be early in December; stout wooden frames, previously prepared, will be inserted in grooves left for that purpose in the piers of the culvert, the spaces between these frames will be filled up with concrete, and the culvert in rear of them will also be filled up with the same material to a total length of 100 feet.

113. The remainder of the culvert will then be filled in with earth, and the opening in its rear filled up. There will be no difficulty in carrying out this by the end of the working season, and the dam will then be complete. Its front slope will be revetted with stone from 151 feet above datum (6 feet below the sill of the cutting) to 196 feet (6 feet above the highest water level of the lake).

114. The execution of the escape and cutting will proceed at the same time with that of the dam. The former does not seem to call for any remark; a few words are required concerning the sluice dam for regulating the discharge through the latter.

115. It has been stated† that the maximum amount of water to be thrown into the Sooroollyar should not greatly exceed one million cubic yards an hour. In order thus to limit the discharge, and at the same time to enable the cutting to pass the ordinary supply of the river with only a moderate depth on its sill, it is proposed to close the upper part of the cutting by a dam, leaving an opening below for the passage of water.

† Paragraph 27.

116. Calculation shows the best arrangement* for this purpose to be three arches with a span of 10 feet, and a height up to the springing line of 6 feet 9 inches above the sill of the cutting. Two piers, 5 feet thick, will make a total width of 40 feet, and the cutting will therefore be enlarged from 30 feet (its ordinary width) to 40 feet, at the site of the sluice dam.

* Plan No. 9.

117. This sluice will pass 160,000 cubic yards an hour, with a depth on the sill of the cutting of a little over 6 feet, while the greatest discharge (with the lake level at 190) will be 1,103,000 cubic yards an hour. Sluice gates may, if necessary, be added still further to regulate the discharge, but they do not appear to be necessary.

118. It is proposed to build the upper part of this dam of concrete; the arches and their piers I propose to build of cut-stone, as it is possible that, in the course of years, concrete might be injured by the constant passage of water through the arches. A masonry dam will be cheaper than one of earth, as the extra length of culverts required for the latter would more than compensate for the saving which would be effected in the upper portion of so small a dam as this. The level of the top of this dam, has been purposely made 4 feet lower than that of the main dam on the Perryaur.

119. The other branches of the general estimate may be very briefly dismissed.

120. The estimate of the road† speaks for itself; the line has been carefully surveyed, and the quantities in the estimate are based upon actual measurements taken along the whole line. The ruling gradient of the ghaut is 1 in 15. At the end of last season, a 6-foot path had been cut from the foot of the ghaut to the saddle‡ to the east of the dam site, and a short length widened out to 18 feet.

† No. V.

‡ B. on Plan No. I.

121. For the Officer's and Overseer's quarters,‖ offices, store-sheds, workshops, etc., I propose to erect wooden huts with thatched roofs; for the workmen and maistries, thatched buildings such as have hitherto been used for every one, officers included, appear suitable, the materials for their construction being found on the spot in unlimited quantities; the cost of providing these is included in the rate for labour.§

‖ Estimate No. VI.

§ Table of Data No. I.

122. On Plans No. 1 and No. 4 are indicated, in a general way, what appear the best positions for the various buildings; but the individual arrangement of these is a matter of executive detail, to which it would be out of place to allude in a report like the present. For the same reason I have not touched on such details, as the mode of collecting, organizing, and paying workmen, although I have naturally given a certain amount of consideration to them.

123. The establishment provided¶ for is:—

¶ Estimate No. VII.

4 Overseers, at Rupees 100 each per month.
2 Medical Subordinates, at Rupees 100 each.

4 Writers and Accountants, at (in all) Rupees 190.
28 Lascars, at Rupees 10 each.

Except during the first and last seasons, when two Overseers and one Medical Subordinate only will be required.

The cost of petty supervision is included in the rate of labour.

124. Provision has been made of Rupees 30,000* on account of preliminary surveys and other similar expenses; nearly this sum had been expended on the project up to the end of February last, and by this time the expenditure will probably be more, but the greater part of it has been spent on the construction of the road, and will come out of the sum (Rupees 1,60,000) provided for that portion of the work. It is believed that the sum named will amply cover the cost of the surveys, etc.

* Estimate No. VIII.

125. A separate estimate† is given of the amount and cost of machinery, tools and plant required, which has afterwards been distributed amongst the principal heads into which the general estimate is divided. No deduction has been made on account of value after use, although some of the machinery, especially that for raising water, making concrete, and stone-breaking, will probably be found very useful in other works.

† No. IX.

126. The rates allowed for labour are those which experience has shown to be necessary. They are much higher than are paid under ordinary circumstances, owing to the extreme unhealthiness of the climate and the necessity for bringing all the food for the workpeople from a distance of 20 miles.

127. The number of workmen required to complete the work in the time named will be nearly as follows:—

Coolies from	700 to 1,100
Miners	200
Carpenters	12
Smiths	20

128. The amount of work expected to be done to the dam in each season is based upon a detailed calculation of the number of days required for executing each 10 feet of height in each of the five parts into which the dam is divided, taking into consideration the supply of water for silting and the proportions to be executed by silting and by manual labour, and the rate of progress thus found is that which we may confidently reckon on being able to attain. It is not at all improbable that we may be able to work faster than this, if we can obtain sufficient labour,‡ or if the day's work of a cooly turns out (though this I do not expect) to be greater than I have allowed.

‡ My calculations have been limited by a *maximum* of 1,100 coolies, *i.e.*, 1,000 available for work, and I am convinced that my estimate of the supply of water for silting is a very moderate one.

129. I cannot conclude this report without acknowledging the assistance rendered by Lieutenants Coaker and Greer, in making the surveys and other preliminary investigations connected with the project. Lieutenant Coaker worked with me from the time when I was first appointed to this duty, and in spite of his

constant bad health, and the extremely arduous nature of the work, his energy never flagged until we were both compelled to quit Madura. Lieutenant Greer was not so long employed on the project, but while he was with me his intelligence* and interest in the work rendered his services extremely valuable. Whoever is eventually employed in superintending the execution of this project could not have better assistance than would be furnished by these two Officers.

130. I believe that the information contained in this report, and the papers forwarded with it, will enable Government to come to a definite conclusion regarding the execution of this project. That the work will be a difficult one, requiring constant care and untiring energy on the part of every one concerned, there can be no doubt; in my own mind there is as little of its entire feasibility.

(Signed) J. PENNYCUICK, Captain, R.E.,
Executive Engineer.

HAMPTON COURT,
14th November 1870.

* I have already mentioned that it was Lieutenant Greer who originally suggested the use of the surplus water of the Chinna Moollyar for obtaining a smaller supply at a higher level, which enables us to do nearly three times as much work by silting as we could do without raising the water in this manner.

TABLE I.—*Table of Rain-fall and discharge of River as observed during* 1869-70.

Months.	Rain-fall. At upper camp.	Rain-fall. At lower camp.	Discharge of River. Total discharge during month.	Discharge of River. Depth run off from drainage area of 250 sqr. miles.	Discharge of River. Maximum during month.	Discharge of River. Minimum during month.	Average. Per day.	Average. Per hour.	Average. Per minute.	Average. Per second.
	Inches.	Inches.	1,000 Cub. yds.	Inches.	Cubic feet. Per second.	Cubic feet. Per second.	1,000 Cub. yds.	1,000 Cub. yds.	Cubic feet.	Cubic feet.
July 1869.	6·25	8·00	89,672	4·17	2,350	435	2,893	120·5	54,244	904
August ,,	8·48	9·96	103,259	4·75	6,322	483	3,331	138·8	62,456	1,041
Sept. ,,	5·47	6·24	68,209	3·17	3,871	354	2,274	94·7	42,637	711
Oct. ,,	10·39	8·57	69,912	3·25	5,780	314	2,255	94·2	42,281	705
Nov. ,,	13·19	14·11	*496,396	23·08	127,129	742	16,547	517·1	310,247	5,171
Dec. ,,	1·56	2·47	100,160	4·66	3,901	454	3,231	134·6	60,581	1,010
Jan. 1870.	0·83	0·85	56,184	2·61	2,348	339	1,812	75·5	33,975	566
Feb. ,,	0·09	0·05	25,566	1·19	609	210	913	38·0	17,118	285

* Of this there passed	During 7th and 8th (Thousand cubic yards).	During 17th to 20th (Thousand cubic yards).
in 3 hours	4,000	46,404
Do. in 6 ,, ...	7,878	82,961
Do. in 12 ,, ...	13,532	136,966
Do. in 24 ,, ...	21,672	209,623
Do. in 48 ,, ...	38,445	280,499
Do. in 96 ,, ...	......	314,073

222 millions (nearly) would have been discharged over the escape.

TABLE II.—*Discharge of the Perryaur at site of Dam for various surface levels.*

Level above datum.	Discharge. Cubic feet per minute.	Discharge. Cubic feet per second.	Discharge. 1,000 cubic yards per hour.	Level above datum.	Discharge. Cubic feet per minute.	Discharge. Cubic feet per second.	Discharge. 1,000 cubic yards per hour.
Feet.				Feet.			
0	21,666	361	48	15	1,720,406	28,673	3,823
1	44,087	735	98	16	1,949,822	32,947	4,333
2	79,534	1,326	177	17	2,189,703	36,495	4,866
3	122,913	2,049	273	18	2,439,806	40,663	5,422
4	182,785	3,046	406	19	2,706,960	45,116	6,015
5	255,187	4,253	567	20	2,995,768	49,929	6,657
6	336,240	5,604	747	21	3,330,166	55,503	7,400
7	428,166	7,136	951	22	3,721,587	62,026	8,270
8	531,089	8,851	1,180	23	4,158,105	69,302	9,240
9	648,369	10,806	1,441	24	4,634,130	77,236	10,298
10	778,386	12,973	1,730	25	5,155,554	85,926	11,457
11	926,767	15,446	2,059	26	5,717,301	95,288	12,705
12	1,095,608	18,267	2,435	27	6,335,480	105,591	14,079
13	1,285,048	21,417	2,856	28	6,976,677	116,278	15,504
14	1,494,633	24,911	3,321	29	7,641,848	127,364	16,982

NOTE.—The datum level of this and other tables is the top of a rock in the bed of the river at the upper or No. 1 site, and very fairly represents the ordinary low-water level of the stream at that point.

The velocities and discharges corresponding to various surface levels from 0 to 37 feet at No. 1 site were ascertained by numerous observations during 1869-70, and the surface fall between sites No. 1 and No. 2 for several levels was also observed; the above table of discharges at No. 2 site has been calculated from the data thus obtained.

The amount of drainage received by the Perryaur between the two sites is very trifling, and has been neglected in this calculation.

Proceedings of the Madras Government, Public Works Department, 4th May 1871.

TABLE III.—*Table of area of Lake surface and content of Lake at various levels.*

Level above datum.	Area of lake surface.	Content of lake.	Total content.
Feet.	1,000 sqr. yds.	1,000 cubic yards.	
0	125·0	222·9	222·9
5	142·5	281·2	504·1
10	195·0	397·9	902·0
15	282·5	572·9	1,474·9
20	405·0	806·3	2,281·2
25	562·5	1,006·2	3,287·4
30	645·0	1,156·3	4,443·7
35	742·5	1,331·2	5,774·9
40	855·0	1,531·3	7,306·2
45	982·5	1,756·2	9,062·4
50	1,125·0	1,962·5	11,024·9
55	1,230·0	2,145·8	13,170·7
60	1,345·0	2,345·8	15,516·5
65	1,470·0	2,562·5	18,079·0
70	1,605·0	2,795·8	20,874·8
75	1,750·0	3,071·7	23,946·5
80	1,936·0	3,391·7	27,338·2
85	2,134·0	3,731·6	31,069·8
90	2,344·0	4,091·7	35,161·5
95	2,566·0	4,471·7	39,633·2
100	2,800·0	4,888·9	

Level above datum.	Area of lake surface.	Content of lake.	Total content.
Feet.	1,000 sqr. yds.	1,000 cubic yards.	
105	3,066·5	4,888·9	44,522·1
110	3,346·0	5,343·7	49,865·8
115	3,638·5	5,820·4	55,686·2
120	3,944·0	6,318·8	62,005·0
125	4,262·5	6,838·7	68,843·7
130	4,619·5	7,401·7	76,245·4
135	4,990·5	8,008·3	84,253·7
140	5,375·5	8,638·3	92,892·0
145	5,774·5	9,291·7	102,183·7
150	6,187·5	9,968·3	112,852·0
155	6,645·0	10,693·7	122,845·7
160	7,117·5	11,468·8	134,314·5
161	7,213·8	2,388·5	136,703·0
162	7,310·7	2,420·8	139,123·8
163	7,408·2	2,453·1	141,576·9
164	7,506·3	2,485·8	144,062·7
165	7,605·0	2,518·5	146,581·2
166	7,704·3	2,551·6	149,132·8
167	7,804·2	2,584·7	151,717·5
168	7,904·7	2,618·2	154,335·7
169	8,005·8	2,651·7	156,987·4
		2,685·6	

Level above datum.	Area of lake surface.	Content of lake.	Total content.
Feet.	1,000 sqr. yds.	1,000 cubic yards.	
170	8,107·5	2,685·6	159,673·0
171	8,209·8	2,719·5	162,392·5
172	8,312·7	2,753·8	165,146·6
173	8,416·2	2,788·1	167,934·4
174	8,520·3	2,822·8	170,757·2
175	8,625·0	2,857·5	173,614·7
176	8,730·3	2,892·6	176,507·3
177	8,836·2	2,927·7	179,435·0
178	8,942·7	2,963·2	182,398·2
179	9,049·8	2,998·7	185,396·9
180	9,157·5	3,034·6	188,431·5
181	9,265·8	3,070·5	191,502·0
182	9,374·7	3,106·8	194,608·8
183	9,484·2	3,143·1	197,751·9
184	9,594·3	3,179·8	200,931·7
185	9,705·0	3,216·5	204,148·2
186	9,816·3	3,253·6	207,401·8
187	9,928·2	3,290·7	210,692·5
188	10,040·7	3,328·2	214,020·7
189	10,153·8	3,365·7	217,386·4
190	10,267·5	3,403·5	220,789·9

Proceedings of the Madras Government, Public Works Department, 4th May 1871.

TABLE IV.—*Table showing rise of Lake surface during an ordinary big fresh. Sill of cutting at 157.*

Level of lake surface.	Content of lake.	Discharge of river	Discharge of cutting.	Stored in lake.	Time.	Total stored above 164 feet level.	Level.	——
Feet.	1,000 C. yards.	1,000 cubic yards per hour.			Hour.	1,000 C. yards.	Feet.	
164 to 165·0	2,518·5	333 500	218	115 282	12·0 4·04	1,380·0	164·55	4 Millions cubic yards in 12 hours.
165 to 166·0	2,551·6	500 750	263	237 487	7·96 1·36	4,415·0	165·74	6 do. in do.
166 to 167·0	2,584·7	...	310	440	5·87			
167 to 168·0	2,618·2	750 1,000	359	391 641	4·77 1·19	9,519·9	167·71	9 do. in do.
168 to 169·0	2,651·7	...	410	590	4·49			
169 to 170·0	2,685·6	...	462	538	5·0			
170 to 171·0	2,719·5	1,000 1,333	515	485 818	1·32 2·50	16,250·5	170·24	12 do. in do.
171 to 172·0	2,753·8	1,333 1,000	565	768 435	3·50 0·16	21,017·8	171·98	8 do. in 6 do.
172 to 173·0	2,788·1	...	612	388	7·19			
173 to 173·58	1,636·8	1,000 437½	648	352	4·65	25,508·5	173·58	12 do. in 12 do.
				Lake commences to fall			... ..	10½ do. in 24 do.

NOTE.—The discharges given in the above table are those assumed by Captain Ryves for "an ordinary big fresh," which was to be exceeded before any water should pass over the [illegible].

No flood of this extent occurred during 1869-70, except the great one on the 17th and 18th November 1869.

The largest fresh next to this occurred on the 7th and 8th November, and would have raised the level of the lake surface to 171·15.

The level of 174 for the escape, as found from the above table, appears therefore suitable.

TABLE V.—*Table showing rise and fall of Lake surface during a great flood. Sill of cutting at 157. Crest of escape at 174.*

Level of lake surface.	Content of lake.	Discharge of river.	Discharge of cutting.	Discharge over escape.	Stored in lake.	Time.	Total stored above 164 feet level.	Level.	——
Feet.	1,000 C. yds.	1,000 cubic yards per hour.				Hour.	1,000 cubic yards.	Feet.	
167 to 168	2,618·2	4,000	359	......	3,641	0·72			
168 to 169	2,651·7	......	410	......	3,590	0·74			
169 to 170	2,685·6	......	462	......	3,538	0·76			
170 to 171	2,719·5	......	515	......	3,485	0·78			
171 to 172	2,753·8	......	565	......	3,435	0·80			
172 to 173	2,788·1	......	612	......	3,388	0·82			
173 to 174	2,822·8	......	655	......	3,345	0·84			
174 to 175	2,857·5	4,000 6,671	693	.95	3,212 5,803	0·54 0·19	28,429·0	174·61	24 millions cubic yds. in 6 hours.
175 to 176	2,892·6	......	727	364	5,580	0·52			
176 to 177	2,927·7	......	757	763	5,151	0·57			
177 to 178	2,963·2	......	786	1,255	4,630	0·64			
178 to 179	2,998·7	......	813	1,824	4,034	0·74			
179 to 180	3,034·6	6,671 8,812	840	2,461	3,370 5,511	0·34 0·34	42,480·0	179·38	20,014,000 do. in 3 hours.

TABLE V.—(Concluded.)

Level of lake surface.	Content of lake.	Discharge of river.	Discharge of cutting.	Discharge over escape.	Stored in lake.	Time.	Total stored above 164 feet level.	Level.	
Feet.	1,000 C. yds.	1,000 cubic yards per hour.				Hour.	1,000 cubic yards.	Feet.	—
180·0 to 181·0	3,070·5	......	866	3,159	4,787	0·64			
181·0 to 182·0	3,106·8	......	892	3,913	4,007	0·78			
182·0 to 183·0	3,143·1	......	918	4,721	3,173	0·99			Cubic yds.
183·0 to 183·10	323·0	......	943	5,577	1,292	0·25	54,012·2	183·10	26,435,000 in 3 hours.
					Drawn from lake.				
183·10 to 183·0	323·0	5,503	943	5,577	1,017	0·32			
183·0 to 182·0	3,143·1	5,503 3,567	918	4,721	136 2,072	2·68 1·35	53,332·8	182·89	16,510,000 in do.
182·0 to 181·34	2,042·7	......	892	3,913	1,238	1·65	48,502·9	181·34	10,700,000 in do.
					Stored				
181·34 to 182·0	2,042·7	10,668	892	3,913	5,863	0·35			
182·0 to 183·0	3,143·1	......	918	4,721	5,029	0·62			
183·0 to 184·0	3,179·8	......	943	5,577	4,148	0·77			
184·0 to 185·0	3,216·5	......	968	6,477	3,223	1·0			
185·0 to 186·0	3,253·6	10,668 15,468	993	7,423	2,252 7,052	0·26 0·38	60,674·0	185·15	32,005,000 in do.
186·0 to 187·0	3,290·7	......	1,018	8,411	6,039	0·54			
187·0 to 188 0	3,328·2	......	1,042	9,449	4,977	0·67			
188·0 to 189·0	3,365·7	......	1,067	10,523	3,878	0·87			
189·0 to 189·48	1,643·4	......	1,085	11,340	3,043	0·54	74,966·9	189·48	46,404,000 in do.
					Drawn from lake.				
189·48 to 189·0	1,643·4	12,186 7,333	1,085	11,340	239 5,092	3·0 0·18	74,259·9	189·27	36,557,000 in do.
189·0 to 188·0	3,365·7	......	1,067	10,523	4,257	0·79			
188·0 to 187·0	3,328·2	......	1,042	9,449	3,158	1·05			
187·0 to 186·0	3,290·7	7,333 5,614	1,018	8,411	2,096 3,815	0·98 0·33	64,575·7	186·38	22,000,000 in do.
186·0 to 185·0	3,253·6	......	993	7,423	2,802	1·16			
185·0 to 184·0	3,216·5	5,614 3,575	968	6,477	1,831 3,870	1·51 0·11	57,320·7	184·15	16,841,000 in do.
184·0 to 183·0	3,179·8	......	943	5,577	2,945	1·08			
183·0 to 182·0	3,143·1	......	918	4,721	2,064	1·52			
182·0 to 181·0	3,106·8	3,575 1,814	892	3,913	1,230 2,991	0·29 0·92	50,199·4	181·89	10,726,000 in do.
181·0 to 180·0	3,070·5	......	866	3,159	2,211	1·39			
180·0 to 179·0	3,034·6	......	840	2,461	1,487	2·04			
179·0 to 178·0	2,998·7	1,814 1,271	813	1,824	823 1,366	1.65 1·20	39,976·3	178·55	10,887,000 in 6 hours.
178·0 to 177·0	2,963·2	......	786	1,255	740	4·0			
177·0 to 176·0	2,927·7	1,271 1,077 1,030	757	763	249 443 490	0·80 6·0 0·14	35,173·1 32,515·1	176·94 176·02	7,624,000 6,461,000
176·0 to 175·0	2,892·6	1,030 836 665	727	364	61 255 426	5.86 6·0 2·36	32,087·1 30,557·1	175·88 175·35	6,180,000 5,017,000 In 6 hours,
175·0 to 174·0	2,857·5	665 542	693	95	123 246	3·64 9·80	29,104·3 26,694·5	174·84 174·0	3,987,000 6,505,000 in 12 hours.

Total amount discharged over escape—221,873,000, cubic yards.

TABLE I.—*Table showing rise of Lake surface from a great flood occurring during the construction of the latter part of the Dam.*

Level of lake surface.	Content of lake.	Discharge of river.	Discharge of culvert.	Stored in lake.	Time.	Level.	
Feet.	1,000 C. yds.	1,000 cubic yards per hour.			Hour.	Feet.	
5 to 10·0	281·2	4,000	633	3,367	0·08		
10 to 15·0	397·9	......	858	3,142	0·13		
15 to 20·0	572·9	......	1,071	2,929	0·20		
20 to 25·0	806·3	......	1,264	2,736	0·30		
25 to 30·0	1,006·2	......	1,688	2,312	0·44		
30 to 35·0	1,156·3	......	2,353	1,647	0·70		
35 to 40·0	1,331·2	......	2,727	1,273	1·05		
40 to 45·0	1,531·3	......	3,017	983	1·56		
45 to 50·0	1,756·2	4,000 6,671	3,278	722 3,393	1·54 0·19	48·17	24 millions cubic yards in 6 hours.
50 to 55·0	1,962·5	......	3,521	3,150	0·62		
55 to 60·0	2,145·8	......	3,753	2,918	0·74		
60 to 65·0	2,345·8	......	3,968	2,703	0·87		
65 to 70·0	2,562·8	6,671 8,812	4,172	2,499 4,640	0·58 0·24	67·83	20,014,000 cubic yards in 3 hours.
70 to 75·0	2,795·8	......	4,366	4,446	0·63		
75 to 80·0	3,071·7	......	4,551	4,261	0·72		
80 to 85·0	3,391·7	......	4,730	4,082	0·83		
85 to 90·0	3,731·6	8,812 5,510	4,904	3,908 606	0·58 2·55	87·93	26,435,000 do. in do.
90 to 90·28	229·5	......	5,000	510	0·45	90·28	16,510,000 do. in do.
				Drawn from lake.			
90·28 to 90·0	229·5	3,567	5,000	1,433	0·16		
90·0 to 85·0	3,731·6	......	4,904	1,337	2·79		
85·0 to 84·92	62·6	......	4,810	1,243	0·05	84·92	10,700,000 do. in do.
				Stored in lake.			
84·92 to 90·0	3,794·2	10,668	4,902	5,764	0·65		
90·0 to 95·0	4,091·7	......	5,071	5,597	0·73		
95·0 to 100·0	4,471·9	10,668	5,231	5,437	0·82		
100·0 to 105·0	4,888·9	10,668 15,468	5,385	5,283 10,083	0·80 0·07	104·32	32,005,000 do. in do.
105·0 to 110·0	5,343·7	......	5,535	9,933	0·54		
110·0 to 115·0	5,820·4	......	5,686	9,782	0·60		
115·0 to 120·0	6,318·8	......	5,972	9,496	0·67		
120·0 to 125·0	6,838·7	......	6,109	9,359	0·73		
125·0 to 130·0	7,401·7	15,468 12,186	6,243	9,225 5,943	0·39 0·64	127·43	46,404,000 do. in do.
130·0 to 135·0	8,008·3	......	6,374	5,812	1·38		
135·0 to 139·66	8,055·4	12,186 7,333 5,614	6,504	5,682 829 Commences to fall.	0·98 3·0	138·22 139·66	36,557,000 do. in do. 22 millions do. in do. 16,841,000 do. in do.

NOTE.—The discharges given in the above Tables (V. and VI.,) are those of a flood which actually occurred on the 17th—20th November 1869. For short periods they are somewhat greater than those of the flood assumed by Captain Ryves as the greatest possible.

There is good evidence that this flood was of very unusual, if not of altogether unprecedented, magnitude; it has therefore been considered advisable to calculate the level to which the lake would rise from it, rather than from an imaginary series of discharges.

HAMPTON COURT,
14th November 1870.

(Signed) J. PENNYCUICK, Captain, R.E.,
Executive Engineer.

QUANT

TABLE I.—*Earth-*

Level above datum.	Right Bank. Mean length.	Right Bank. Mean breadth.	Right Bank. Area of horizontal section.	Right Bank. Content.	Left Bank. Mean length.	Left Bank. Mean breadth.	Left Bank. Area of horizontal section.	Left Bank. Content.	150 Feet Dam in Mean length.	150 Feet Dam in Mean breadth.
Feet.	Feet.	Feet.	Sq. Ft.	Cub. yds.	Feet.	Feet.	Sq. Ft.	Cub. yds.	Feet.	Feet.
				300				5,789		
0	......	......	5,000		58 − 143	× 1,061 × 66	= 52,100		120 − 240	× 770 × 66 =
				2,370				23,313		
10	......	......	7,800		77 − 156	× 1,011 × 26	= 73,791		130 − 260	× 720 × 26 =
				3,815				30,571		
20	......	......	12,800		95	× 961	= 91,295		140	× 670 =
				7,107				34,283		
30	48 − 65	× 912 × 280	= 25,576		103	× 911	= 93,833		155	× 620 =
				14,792				34,895		
40	83 − 65	× 861 × 264	= 54,303		110	× 860	= 94,600		175	× 570 =
				24,943				34,919		
50	119 − 65	× 811 × 248	= 80,389		116	× 810	= 93,960		195	× 520 =
				32,502				36,234		
60	145 − 65	× 760 × 232	= 95,120		134	× 759	=101,706		215	× 470 =
				37,761				38,923		
70	173 − 65	× 710 × 216	=108,790		153	× 709	=108,477		235	× 420 =
				43,489				40,316		
80	211 − 65	× 659 × 200	=126,049		166	× 658	=109,228		255	× 370 =
				50,289				40,044		
90	259 − 65	× 608 × 184	=145,512		176	× 608	=107,008		275	× 320 =
				56,694				38,899		
100	308 − 65	× 557 × 168	=160,636		185	× 557	=103,045		295	× 270 =
				58,995				37,917		
110	331 − 65	× 507 × 152	=157,937		201	× 506	=101,706		315	× 220 =
				57,673				36,990		
120	356 − 65	× 456 × 136	=153,496		215	× 456	= 98,040		335	× 170 =
				55,250				35,481		
130	376 − 65	× 406 × 120	=144,856		231	× 405	= 93,555		355	× 120 =
				51,146				33,694		
140	389 − 65	× 355 × 104	=131,335		249	× 355	= 88,395		375	× 70 =
				46,024				31,288		
150	403 − 65	× 305 × 88	=117,195		265	× 304	= 80,560		395	× 20 =
				40,451				28,277		
160	417 − 65	× 254 × 72	=101,238		284	× 254	= 72,136			
				34,356				24,711		
170	431 − 65	× 204 × 56	= 84,284		302	× 203	= 61,306			
				28,217				20,505		
180	462 − 65	× 153 × 40	= 68,086		323	× 153	= 49,419			
				22,009				15,668		
190	508 − 65	× 103 × 24	= 50,764		345	× 102	= 35,190			
				14,639				9,992		
200	554 − 65	× 52 × 8	= 28,288		368	× 51	= 18,768			
				4,039				2,657		
205	568	× 27	= 15,336		382	× 26	= 9,932			
	Total up to 120 feet ...			390,730	Total up to 110 feet ...			396,103		
	,, above ,, ,, ...			296,131	,, above ,, ,, ...			239,263		
				686,861				635,366		

31

TIES.

ork in Dam.

NTRAL OPENING.		REMAINDER OF CENTRAL OPENING.				OPENING OVER END OF CULVERT.				
rea of rizontal ection.	Content.	Mean length.	Mean breadth.	Area of horizontal section.	Content.	Mean length.	Mean breadth.	Area of horizontal section.	Content.	Total Content.
q. Ft.	Cub. yds.	Feet.	Feet.	Sq. Ft.	Cub. yds.	Feet.	Feet.	Sq. Ft.	Cub. yds.	Cub. yds.
	8,396				3,920				811	19,216
75,560		120 ×	294	= 35,280		40 × + 27 ×	365 552	= 29,504		
	30,074				13,067				11,946	80,770
86,840		120 ×	294	= 35,280		60 × + 27 ×	335 552	= 35,004		
	33,452				13,067				13,761	94,666
93,800		120 ×	294	= 35,280		80 × + 27 ×	305 552	= 39,304		
	35,167				13,157				9,654	99,368
96,100		do. + 35 ×	14	= 35,770		100 ×	280	= 28,000		
	36,269				13,463				11,052	110,471
99,750		do. + 55 ×	30	= 36,930		120 ×	264	= 31,680		
	37,250				14,011				12,296	123,419
01,400		do. + 75 ×	46	= 38,730		140 ×	248	= 34,720		
	37,491				14,796				13,304	134,327
01,050		do. + 95 ×	62	= 41,170		160 ×	232	= 37,120		
	36,991				15,819				14,074	143,568
8,700		do. + 115 ×	78	= 44,250		180 ×	216	= 38,880		
	35,750				17,078				14,607	151,240
4,350		do. + 135 ×	94	= 47,970		200 ×	200	= 40,000		
	33,769				18,574				14,904	157,580
8,000		do. + 155 ×	110	= 52,330		220 ×	184	= 40,480		
	31,046				20,307				14,963	161,909
9,650		do. + 175 ×	126	= 57,330		240 ×	168	= 40,320		
	27,583				22,278				14,785	161,558
9,300		do. + 195 ×	142	= 62,970		260 ×	152	= 39,520		
	23,380				24,485				14,370	156,898
6,950		do. + 215 ×	158	= 69,250		280 ×	136	= 38,080		
	18,435				26,930				13,719	149,815
2,600		do. + 235 ×	174	= 76,170		300 ×	120	= 36,000		
	12,750				29,611				12,830	140,031
6,250		do. + 255 ×	190	= 83,730		320 ×	104	= 33,280		
	6,324				32,530				11,704	127,870
7,900		do. + 275 ×	206	= 91,930		340 ×	88	= 29,920		
					33,226				10,341	112,295
		415 × — 295 ×	262 72	= 87,490		360 ×	72	= 25,920		
					30,013				8,741	97,821
		435 × — 315 ×	212 56	= 74,580		380 ×	56	= 21,280		
					24,980				6,904	80,606
		455 × — 335 ×	162 40	= 60,310		400 ×	40	= 16,000		
					19,355				4,830	61,862
		475 × — 355 ×	111 24	= 44,205		420 ×	24	= 10,080		
					13,222				2,519	40,372
		495 × — 375 ×	61 8	= 27,195		440 ×	8	= 3,520		
					4,201				326	11,223
		505 × — 385 ×	36 0	= 18,180		450 ×	0	= 0		
		Total up to 120 feet ...			204,022					
		,, above ,, ,, ...			214,068					
tal...	444,127				418,090		Total ...		232,441	2,416,885

Proceedings of the Madras Government, Public Works Department,
4th May 1871.

Table II.—*Abstract showing amount of Work to be executed in each Season.*

	To be executed by silting.					To be executed by manual labour.	Total.
	From Right Bank.		From Left Bank.		Total executed by silting.		
	Below main channel.	Above main channel.	Below main channel	Above main channel.			
2nd Season.	Cub. yds.	Cub. yds.	Cub. yds.	Cub. yds.	Cub. yds.	Cub. yds.	Cub. yds.
Right bank up to 120 feet	26,762	303,215	......	......	329,977	60,753	390,730
Left bank up to 110 feet	......	......	232,674	109,942	342,616	53,487	396,103
	26,762	303,215	232,674	109,942	672,593	114,240	786,833
3rd Season.							
Right bank from 120 to 205 feet... ...	......	239,296	......	......	239,296	56,835	296,131
Left bank from 110 to 205 feet... ...	......	......	......	134,201	134,201	105,062	239,263
	......	239,296	......	134,201	373,497	161,897	535,394
4th Season.							
150 feet dam in central opening	280,676	84,008	66,695	12,748	444,127	......	444,127
Remainder of central opening up to 120 feet	28,585	44,235	47,565	64,689	185,074	18,948	204,022
	309,261	128,243	114,260	77,437	629,201	18,948	648,149
5th Season.							
Central opening ...	......	126,558	......	......	126,558	87,510	214,068
Opening over end of culvert	64,502	91,170	21,795	22,489	200,206	32,485	232,441
	64,502	217,728	21,795	22,489	326,764	119,995	446,509
Total...	400,525	888,482	368,729	344,069	2,002,055	415,080	2,416,885

Table III.—*Table showing amount of Earth available for Silting.*

Level at which earth can be brought to dam.	Right Bank.		Left Bank.		Level.	Right Bank.		Left Bank.	
	Below main channel.	Above main channel.	Below main channel.	Above main channel.		Below main channel.	Above main channel	Below main channel.	Above main channel.
	C. yds.	C. yds.	C. yds.	C. yds.		C. yds.	C. yds.	C. yds.	C. yds.
From 0 to 25 feet ...	171,000	2,000	213 000	94,000	100 to 125 feet...	4,000	174,000	13,000	78,000
25 to 50 ,, ...	117,000	25,000	134,000	86,000	125 to 150 ,, ...	...	139,000	...	76,000
50 to 75 ,, ...	95,000	135,000	82,000	86,000	above 150 ,, ...	...	327,000	...	53,000
75 to 100 ,, ...	37,000	96,000	42,000	76,000					

TABLE IV.—*Quantities in temporary rough Stone Dams.*

Level above datum.	Upper.				Lower.				
	Length.	Breadth.	Area of section.	Content.	Length.	Breadth.	Area of section.	Content.	Total Content.
Feet.	Feet.	Feet.	Sq. ft.	C. yds.	Feet.	Feet.	Sq. ft.	C. yds.	C. yds.
0	178 ×	66 =	11,748	1,305	205 ×	66 =	13,530	1,503	2,808
5	188 ×	46 =	8,648	1,889	212 ×	46 =	9,752	2,156	4,045
10	198 ×	26 =	5,148	1,277	218 ×	26 =	5,668	1,428	2,705
15	208 ×	6 =	1,248	592	225 ×	6 =	1,350	742	1,334
			Total ...	5,063			Total ...	5,829	10,892

TABLE V.—*Quantities of Stone Revetment.*

Mean length.	Mean breadth (height).	Area.	Area.	—
Feet.	Feet.	Sq. ft.	Sq. yds.	
816 ×	$\frac{78+64}{2}$ =	57,936		Left side of central opening.
110 ×	$\frac{78}{2}$ =	4,290		
135 ×	$\frac{64}{2}$ =	4,320	7,394	
586 ×	$\frac{39+24}{2}$ =	18,453		Right do. do. (over culvert).
55 ×	$\frac{39}{2}$ =	1,072½		
17½ ×	$\frac{24}{2}$ =	210	2,193	
$\frac{287+207}{2}$ ×	71 =	17,537	....	Right side of opening below culvert.
$\frac{287+207}{2}$ ×	71 =	17,537	....	Left do. do. do.
$\frac{40+140}{2}$ × — 40 ×	86 52 } =	5,680	5,639	Rear slope of dam above end of do.
1,265 ×	101 =	127,765	14,196	Front slope of dam from 151 to 196 foot level.
358 ×	133 =	47,614	5,290	Rear do. do. from 2 to 40 do.
		Total ...	34,712	

TABLE VI.—*Quantities in Culvert.*

Number.	Length.	Breadth or thickness.	Height.	Content.	—
	Feet.	Feet.	Feet.	C. feet.	
	658 ×	4[illegible] ×	27½ =	778,085	Culvert.
3 ×	658 ×	[illegible] ×	20½ } =	427,042	Deduct for opening up to springing of arches.
3 ×	658 ×	*s. f.* 31⅚	}		Do. do. above do.
				351,043	
4 ×	9 ×	4 ×	27½ =	3,960	Projecting portion of piers at upper end.
4 ×	667 ×	5 ×	4 =	53,360	Foundation of piers.
43 ×	43 ×	3 ×	3 =	387	Cross retaining wall at lower end.
2 ×	19 ×	4 ×	21 =	3,192	Side do. do. do.
2 ×	18 ×	2 ×	7 =	504	Do. do. do. do.
2 ×	19 ×	5 ×	4 =	760	Foundation of side retaining walls.
2 ×	18 ×	3 ×	2 =	216	Do. do. do. do.
			Total ...	413,422	Portland cement concrete.
				54,336	Trenching rock for foundation.

TABLE VII.—*Quantities in silting Dams.*

Chinna Moollyar.				Avinashi Stream.				
Length.	Height.	Thickness.	Content.	Length.	Height.	Thickness.	Content.	—
Feet.	Feet.	Feet.	C. Feet.	Feet.	Feet.	Feet.	C. Feet.	
10[illegible] ×	[illegible] ×	5	1,287½	120½ ×	2½ ×	4 =	1,205	Dam.
94½ ×	2½ ×	6	1,417½	107 ×	2½ ×	5 =	1,337½	
85½ ×	2[illegible] ×	7	1,496¼	90 ×	2½ ×	6 =	1,350	
[illegible] ×	2½ ×	8	1,540	68 ×	2½ ×	7 =	1,190	
[illegible] ×	2½ ×	9	1,305	...	...	...	......	
45 ×	4 ×	11	1,980	57 ×	4 ×	9 =	2,052	Foundation in bed of stream.
76 ×	2½ ×	3	570	...	...	...	......	Wing wall to protect head of channel.
73½ ×	2½ ×	3½	643⅛	...	...	...	......	
70 ×	2½ ×	4	700	59 ×	2½ ×	3 =	442½	
67½ ×	2½ ×	4½	759⅜	46½ ×	2½ ×	3½ =	406⅞	
47 ×	2½ ×	5	587½	38½ ×	2½ ×	4 =	385	
40 ×	2½ ×	5½	550	21½ ×	2½ ×	4½ =	239⅜	
33 ×	2½ ×	6	495	15 ×	2½ ×	5 =	187½	
26 ×	2½ ×	6½	422½	...	...	...	......	
19 ×	2½ ×	7	332½	...	...	...	......	
			14,086¼	...	...	...	8,795¾	Total Portland cement concrete
			3,800	...	...	...	2,967	Trenching rock for foundations.
32	21 inches diameter		......	30	21 inches diameter		......	Earthen pipe.

TABLE VIII.—*Quantities in Escape.*

Distance from west end of escape.	Rock.		Earth.	
	Area of section.	Content.	Area of section.	Content.
Feet.	Sq. ft.	C. yds.	Sq. ft.	C. yds.
100	2,035	3,769	649	1,202
200	1,942	7,365	1,020	3,[illegible]91
300	1,603	6,565	1,086	3,900
400	1,588	5,909	822	3,[illegible]33
500	6,595	15,154	2,039	5,298
600	9,780	30,324	5,009	13,052
700	12,092	40,504	2,567	14,030
800	8,222	37,619	2,066	8,580
900	6,942	28,081	1,019	5,713
1,000	5,838	23,667	1,032	3,798
1,100	1,583	13,743	1,161	4,061
1,200	643	4,022	963	3,933
1,300	....	953	106	1,980
	Total ...	217,675	...	72,171

NOTE.—The earth removed from the escape will be used in the construction of the dam, but as it will not be required for the latter until some time after, it must be removed from the former; it is necessary to provide for removing it by manual labour, as well as for transporting it to the dam by silting.

TABLE IX.—*Quantities in cutting through Water-shed.*

Distance from Water-shed line.		Rock.		Earth.	
		Area of section.	Content.	Are[illegible] sectio[illegible]	
Feet.		Sq. ft.	C. yds.	Sq. ft.	C. yds.
			308		183
South	900	111		40	
			1,989		622
	600	238		72	
			3,117		956
	300	323		100	
			4,078		850
North	0	411		53	
			5,083		753
	300	504		79	
			3,311		572
	600	92		24	
			153		64
Total...		......	17,989	......	3,980

TABLE X.—*Quantities in Sluice Dam on Water-shed.*

Length.	Height.	Thickness.	Content.
Feet.	Feet.	Feet.	C. Feet.
$135\frac{1}{2}$ ×	5 ×	5 =	$3,387\frac{1}{2}$
126 ×	5 ×	6 =	3,780
115 ×	5 ×	7 =	4,025
102 ×	5 ×	8 =	4,[illegible]80
86 ×	5 ×	9 =	3,870
67 ×	5 ×	10 =	3,350
Total Portland cement concrete ...		...	$22,492\frac{1}{2}$

Number.	Length.	Height.	Thickness.	Content.	——
	Feet.	Feet.	Feet.	C. Feet.	
	48 ×	14 ×	16 =	10,752	Lower part of dam.
3 ×	10 ×	$6\frac{3}{4}$ ×	16	6,935 (for the three lines)	Deduct for opening up to springing of arches.
3 ×	$\frac{10^2\ \pi}{8}$	×	16		Do. do. above do.
3 ×	$\frac{(14^2-10^2)\pi}{8}$	×	16		Do. do. archwork.
				3,817	
2 ×	7 ×	4 ×	18 =	1,008	Foundation of piers. (for the two lines)
2 ×	5 ×	4 ×	18 =	720	
				5,545	Total cut-stone in cement.
3 ×	$\frac{(14^2-10^2)\pi}{8}$	×	16 =	1,810	Archwork of do. do.
				5,207	Trenching rock for foundations.

——

TABLE XI.—*Quantities in Bridges on Road and Ghaut.*

[illegible]ber.	[illegible]gth.	Height.	Breadth or Thickness.	Content.	——
	Feet.	Feet.	Feet.	C. Feet.	
					1st Class. (Sairveyellar stream, Palgatchemadu stream, and two streams at foot of ghaut.)
2 ×	$\frac{18+54}{2}$ ×	12 ×	3 =	2,592	Piers.
2 ×	54 ×	3 ×	4 =	1,296	Foundations.
		Total Masonry...		3,888	
				1,296	Trenching rock for foundations.
	18 ×		12 =	(Sq. feet.) 216	Superstructure of timber, bamboos, and earth.

TABLE XI.—(Concluded.)

Number.	Length.	Height.	Breadth or Thickness.	Content.	
	Feet.	Feet.	Feet.	C. Feet.	*2nd Class.* (10 Streams.)
2 ×	$\frac{18+36}{2}$ ×	6 ×	$2\frac{1}{2}$ =	810	Piers.
2 ×	36 ×	2 ×	3 =	432	Foundations.
			Total Masonry...	1,242	
				432	Trenching rock for foundations.
	18 ×		8 =	(Sq. feet.) 144	Superstructure.
					3rd Class. (15 Streams.)
2 ×	$\frac{18+30}{2}$ ×	4 ×	2 =	384	Piers.
2 ×	30 ×	$1\frac{1}{2}$ ×	$2\frac{1}{2}$ =	225	Foundations.
			Total Masonry...	609	
				225	Trenching rock for foundations.
	18 ×		6 =	(Sq. feet.) 108	Superstructure.

HAMPTON COURT,
14th November 1870.

(Signed) J. PENNYCUICK, Captain, R. E.,
Executive Engineer.

I.—DATA FOR ESTIMATING COST OF LABOUR.

		RS.	A.	P.
1,000 Coolies for 25 working days, at 8 Annas per diem	...	12,500	0	0
25 Maistries do. do. 1 Rupee do.	...	625	0	0
120 Sick men do. do. 4 Annas do.	...	750	0	0
3 Do. Maistries do. do. 8 ,, do.	...	37	8	0
Hutting for 1,120 men, at Rs. 4-8-0 Per season of eight months.	...	630	0	0
Do. for 28 maistries, at ,, 6-0-0 Per season of eight months.	...	21	0	0
Warm clothing for 1,120 men, at ,, 3-0-0 Per season of eight months.	...	420	0	0
Do. for 28 maistries, at ,, 4-0-0 Per season of eight months.	...	14	0	0
Total cost of 1,000 men per month of 25 working days	...	14,997	8	0
Do. 1 man do. do.	...	14	15	11·5
Do. 1 ,, per day ...	...	0	9	7·18
		(= 10 Annas nearly.)		

Other labour to be calculated in proportion, 25 per cent. being added to the actual rate of daily pay on account of sick men, maistries, warm clothing, etc.

II.—Data for estimating cost of Earth-work by Silting Process.

For attending to 12 miles of main channel, at 5 coolies per mile	...	60 Coolies.
Do. do. branch channels	...	20 ,,
Do. do. dam ...	...	40 ,,
Excavating 3,600 cubic yards of earth, at 10 cubic yards per man	...	360 ,,
Total labour for executing 3,600 cubic yards of earth-work...		480 ,,
Cost of do. at 10 Annas per cooly...	Rupees...	300

3,600 cubic yards for Rupees 300 = 12 cubic yards for one Rupee, or Rupees 0-1-4 per cubic yard.

III.—Data for estimating cost of Earth-work by Manual Labour.

		RS.	A.	P.
Excavating 1,000 cubic yards of earth ...	250 coolies, at 10 Annas ...	156	4	0
Clearing stones, roots, etc.	30 do. do. ...	18	12	0
Loading waggons...	125 do. do. ...	78	2	0
Unloading, spreading, ramming, etc. ...	75 do. do. ...	46	14	0
Laying and re-laying rails	6 carpenters, at Rs. 1¼ ...	7	8	0
Do. do.	40 coolies	25	0	0
Transport to dam 160 bullocks, at Rupee 1	...	160	0	0
Total cost of 1,000 cubic yards of earth...		492	8	0
Do. 1 do. do. ...		0	7	10·56

(= 8 Annas nearly.)

IV.—Data for estimating cost of Portland Cement Concrete.

(a.)—Cement.

	RS.	A.	P.
Cost of cement in England, £ 1-12-6 per ton	16	4	0
Freight to Negapatam	25	0	0
[illegible]n Negapatam to the Perryaur	40	0	0
Total cost per ton...	81	4	0

(b.)—Sand and Shingle.

	RS.	A.	P.
Excavating 24 cubic yards, 6 coolies, at 10 Annas	3	12	0
Transport to site of dam, one boat's crew of 4 men, at 10 Annas ... (Four trips per day, 6 cubic yards at each trip.)	2	8	0
Total for 24 cubic yards...	6	4	0
Do. 1 do. ...	0	4	2

(c.)—Broken Stone.

The stone removed for forming the escape will be used for the concrete. It will be broken up by machinery driven by water power; the only expense will therefore be the pay of two men to look after the machine, and the cost of transporting the stone from the escape to the dam.

4 Annas per cubic yard will cover this.

(d.)—Labour for mixing and laying.

The concrete will be mixed by machinery driven by water power. One machine will manufacture 80 cubic yards in a day of 9 hours, the cost of which will be as follows :—

	RS.	A.	P.
Loading machine, spreading, etc., 12 coolies, at 10 Annas	7	8	0
Working and superintending machine, 2 men, at Rupees $1\frac{1}{4}$	2	8	0
Total for 80 cubic yards or 2,160 cub. feet...	10	0	0

	RS.	A.	P.
290 cubic feet of concrete, weighs 27,550 lbs. at Rs. 81-4-0 per ton ...	1,023	9	8
580 do. sand ... ... at ,, 0-4-2 per cub. yd.	5	9	6
580 do. shingle ... ... at ,, 0-4-2 do. ...	5	9	6
1,450 do. broken stone ... ... at ,, 0-4-0 do. ...	13	6	10
Labour for mixing, laying, etc.	10	0	0
Centering, framing, etc.	21	12	6
Total cost of 2,160 cubic feet of concrete...	1,080	0	0
Do. 1 cubic foot do. ...	0	8	0

V.—Data for estimating cost of Silting Channels.

(a.)—Right bank, fed from Chinna Moollyar.

Breadth at top 6 feet, depth 2 feet, side slopes $\frac{1}{2}$ to 1. Channel to be entirely in excavation, the earth thus removed to be formed into an embankment on the outside. The natural slope of the ground being taken at an average of 3 to 1 ; area of section to be excavated will be $\frac{1}{2} \times (6+4) \times 2 + \frac{1}{2} \times \frac{2}{5} \times 6 \times 6 = 10 + 7\frac{1}{5} = 17\frac{1}{5}$ square feet or $51\frac{3}{5}$ cubic feet (= 2 cubic yards nearly) per yard of channel. 2 cubic yards at 4 Annas = 8 Annas.

(b.)—Left bank, fed from Avinashi Stream.

Breadth at top 5 feet, depth 2 feet ; area of section to be excavated $= \frac{1}{2} \times (5 + 3) \times 2 + \frac{1}{2} \times \frac{2}{5} \times 5 \times 5 = 8 + 5 = 13$ square feet or 39 cubic feet (= $1\frac{1}{2}$ cubic yards nearly) per yard of channel. $1\frac{1}{2}$ cubic yards at 4 Annas = 6 Annas.

Clearing ground (both banks), 1 Anna per yard.

Bamboo trestles and wooden troughs for crossing ravines, 5 Rupees per yard.

VI.—Data for estimating cost of Blasting.

750 Miners, at 15 Annas per diem	70[illegible]	[illegible]	[illegible]
400 Coolies, at 10 ,, do.	250	0	[illegible]
720 lbs. of powder, at 6 Annas per lb.	270	0	0
1,600 yards of match, at $\frac{1}{4}$ Anna per yard	25	0	0
60 lbs. of steel, at 8 Annas per lb.	30	0	0
800 ,, of iron, at 2 do.	100	0	0
8 Carpenters, at Rupees 1-4-0 each	10	0	0
8 Smiths, at do. do.	10	0	0
1 month's work of a forge	50	0	0
Sundries	51	14	0
Total cost of blasting and removing 1,000 cubic yards...	1,500	0	0
Do. do. do. 1 cubic yard ...	1	8	0

Note.—The above charges are for the escape. For the blasting in the cutting through the water-shed and on the road, 4 Annas per cubic yard extra has been allowed, as the conditions are not so favourable for getting out the rock in large quantities.

Hampton Court,
14*th November* 1870.

(Signed) J. PENNYCUICK, Captain, R.E.,
Executive Engineer.

ESTIMATES.

I.—*Silting Apparatus and Channels.*

Quantity.	—	Rate.	Amount.	Total.
	(a.)—Right Bank.	RS. A. P.	RS. A. P.	RS. A. P.
14,086 c. f. ...	Portland cement concrete ...	0 8 0	7,043 0 0	
3,800 ,, ...	Trenching rock for foundations...	0 2 0	475 0 0	
32 r. f. ...	21 inches earthen pipe	8 0 0	256 0 0	
	Total for Dam...	....	7,774 0 0	
......	Reservoirs for storing water ...	....	5,000 0 0	
7,883⅓ yds. ...	Main channel	0 9 0	4,434 6 0	
12,000 ,, ...	Branch channels	0 1 0	750 0 0	
450 ,, ...	Trestles, etc., for crossing ravines.	5 0 0	2,250 0 0	
......	Repairs (40 per cent. on main channel)	....	2,673 12 0	
......	Blasting, puddling, contingencies, etc.	....	1,117 14 0	
				24,000 0 0
	(b.)—Left Bank.			
8,796 c. f. ...	Portland cement concrete ...	0 8 0	4,398 0 0	
2,967 ,, ...	Trenching rock for foundations...	0 2 0	370 14 0	
30 r. f. ...	21 inches earthen pipe	8 0 0	240 0 0	
			5,008 14 0	
......	Reservoirs for storing water ...	....	3,000 0 0	
11,520 yds. ...	Main channel	0 7 0	5,040 0 0	
8,000 ,, ...	Branch channels	0 1 0	500 0 0	
480 ,, ...	Trestles, etc., for crossing ravines.	5 0 0	2,400 0 0	
......	Repairs (40 per cent. on main channel)	....	2,976 0 0	
......	Blasting, puddling, contingencies, etc.	....	1,075 2 0	
				20,000 0 0
......	Machinery for raising water ...	....	....	50,000 0 0
	Total...	....	....	94,000 0 0

II.—*Dam and Culvert.*

Quantity.	—	Rate.	Amount.	Total.
	(a.)—Dam.	RS. A. P.	RS. A. P.	RS. A. P.
2,001,805 c. y.	Earth executed by silting ...	0 1 4	1,66,817 1 4	
415,080 ,, ...	Do. by manual labour ...	0 8 0	2,07,540 0 0	
10,892 ,, ...	Rough-stone for temporary dams.	0 8 0	5,446 0 0	
34,712 s. y.	Do. for revetment ...	0 10 0	21,695 0 0	
800,000 ,, ...	Clearing ground	0 0 3	12,500 0 0	
				4,13,998 1 4
	(b.)—Culvert.			
413,422 c. f.	Portland cement concrete ...	0 8 0	2,06,711 0 0	
54,336 ,, ...	Trenching rock for foundations...	0 2 0	6,792 0 0	
1,500 s. f.	Timber framing for closing arches	1 8 0	2,250 0 0	
				2,15,753 0 0
......	Tools, plant, and machinery ...	... .	....	89,600 0 0
......	Sundry charges, contingencies, etc.	....	....	67,648 14 8
	Total...	....	....	7,87,000 0 0

III.—*Escape.*

Quantity.	—	Rate.	Amount.	Total.
		RS. A. P.	RS. A. P.	RS. A. P.
217,675 c. y....	Blasting and removing rock ...	1 8 0	3,26,512 8 0	
72,171 ,, ...	Removing earth	0 4 0	18,042 12 0	
......	Tools, plant, and machinery ...	....	20,400 0 0	
......	Sundry charges, contingencies, etc.	....	15,044 12 0	
	Total...	... .	....	3,80,000 0 0

IV.—*Cutting through Water-shed and Sluice Dam.*

Quantity.	—	Rate.	Amount.	Total.
	(*a.*)—*Cutting.*	RS. A. P.	RS. A. P.	RS. A. P.
17,989 c. y. ...	Blasting and removing rock ...	1 12 0	31,480 12 0	
3,980 ,, ...	Removing earth	0 4 0	1,995 0 0	33,475 12 0
	(*b.*)—*Sluice Dam.*			
22,492½ c. f. ...	Portland cement concrete ...	0 8 0	11,246 4 0	
5,545 ,, ...	Cut-stone in cement	0 12 0	4,158 12 0	
1,810 ,, ...	Archwork of cut-stone in cement.	1 0 0	1,810 0 0	
5,207 ,, ...	Trenching rock for foundations...	0 2 0	650 14 0	17,865 14 0
......	Tools, plant, and machinery ...	....	....	2,200 0 0
......	Sundry charges, contingencies, etc.	....	....	2,458 6 0
	Total...	....	....	56,000 0 0

V.—*Road.*

Quantity.	—	Rate.	Amount.	Total.
	(*a.*)—*Road from foot of Ghaut to site of Dam.*	RS. A. P.	RS. A. P.	RS. A. P.
7,339 yds. ...	Clearing ground (thick jungle)...	0 1 6	688 0 6	
8,917 ,, ...	Do. do. (small do.) ...	0 1 0	557 5 0	
17,932 c. y. ...	Excavating earth	0 4 0	4,483 0 0	
4,835 ,, ...	Do. gravel and small stones.	0 5 0	1,510 15 0	
6,644½ ,, ...	Blasting and removing rock ...	1 12 0	11,627 14 0	
55,999½ ,, ...	Large boulders requiring blasting.	0 12 0	41,999 10 0	
22,388½ ,, ...	Do. do. do. ...	0 8 0	11,194 4 0	
6,980 ,, ...	Do. not requiring blasting.	0 6 0	2,617 8 0	
9,904 ,, ...	Embankment (earth)	0 8 0	4,952 0 0	
1,130 ,, ...	Dry-stone revetment walls ...	1 0 0	1,130 0 0	

V.—*Road.*—(Concluded.)

Quantity.		Rate.	Amount.	Total.
		RS. A. P.	RS. A. P.	RS. A. P.
16,256 yds ...	Drains along inside of road ...	0 0 3	254 0 0	
16,256 ,, ...	Metalling 12 feet broad ...	0 8 0	8,128 0 0	
				89,142 8 6
	Bridges (1st Class.)			
3,888 c. f....	Rubble masonry in chunam ...	0 4 0	972 0 0	
1,296 ,, ...	Trenching rock for foundations...	0 2 0	162 0 0	
216 s. f....	Superstructure	0 6 0	81 0 0	
......	Four bridges each	....	1,215 0 0	
				4,860 0 0
	Bridges (2nd Class.)			
1,242 c. f....	Rubble masonry in chunam ...	0 4 0	310 8 0	
432 ,, ...	Trenching rock for foundations.	0 2 0	54 0 0	
144 s. f....	Superstructure	0 6 0	54 0 0	
......	Ten bridges each	....	418 8 0	
				4,185 0 0
	Bridges (3rd Class.)			
609 c. f....	Rubble masonry in chunam ...	0 4 0	152 4 0	
225 ,, ...	Trenching rock for foundations...	0 2 0	28 2 0	
108 s. f....	Superstructure	0 6 0	40 8 0	
......	Fifteen bridges each	....	220 14 0	
				3,313 2 0
	(b.)			
2,800 yds....	Branch roads about site of dam.	1 4 0	3,500 0 0	1,01,500 10 6
4,000 ,, ...	Footpaths	0 8 0	2,000 0 0	
	(c.)			
14,960 ,, ...	Road from Cumbum to foot of Ghaut	1 12 0	26,180 0 0	5,500 0 0
......	Tools, plant, and machinery ...	....		26,180 0 0
......	Sundry charges, contingencies, etc.	....	....	800 0 0
		....	....	6,019 5 6
	Total...	....	....	1,40,000 0 0

VI.—*Buildings.*

Quan[tity.]		Rate.	Amount.	Total.
		RS. A. P.	RS. A. P.	RS. A. P.
2,700 s. f. ...	Quarters for 3 Officers	2 8 0	6,750 0 0	
960 ,, ...	Office	2 8 0	2,400 0 0	
2,160 ,, ...	Quarters for 4 Overseers ...	2 4 0	4,860 0 0	
12,000 ,, ...	Hospital for 120 Coolies ...	2 0 0	24,000 0 0	
2,000 ,, ...	Do. for 20 Maistries or skilled workmen	2 0 0	4,000 0 0	
5,000 ,, ...	Workshops, sawpits, forges, storesheds, etc.	1 12 0	8,750 0 0	
540 ,, ...	3 Powder Magazines, each for 250 barrels	4 8 0	2,430 0 0	
......	Repairs 8 per cent. for 5 seasons.	....	....	53,190 0 0
......	Sundries...	....	....	21,276 0 0
				534 0 0
	Total...	....	....	75,000 0 0

Proceedings of the Madras Government, Public Works Department,
4th May 1871

VII.—*Establishment.*

	Rate.	Amount.	Total.
	RS.	RS.	RS.
2 Overseers for 40 months	100	8,000	
2 Do. for 24 do.	100	4,800	
2 Writers and Accountants for 40 months	40	3,200	
1 Do. do. do. for 40 do.	50	2,000	
1 Do. do. do. for 40 do.	60	2,400	
1 Medical Subordinate for 40 do.	100	4,000	
1 Do. do. for 24 do.	100	2,400	
28 Lascars for 40 months	10	11,200	
Total...	.....	.....	38,000

VIII.—*Preliminary Expenses.*

Expenses of preliminary surveys and investigations ... ... RS. 30,000

IX.—*Tools, Plant, and Machinery.*

	RS.	A.	P.	RS.	A.	P.
(a.)—Railway Materials.						
12,000 yards of rail, 9 lbs. to the yard, at Rupees 225 per ton.	10,848	3	5			
60,000 feet of sleepers, at Rupees 40 per 100 running feet ...	24,000	0	0			
5,000 dozen nails, 2½ lbs. to the dozen, at 3 dozens for 1 Rupee.	1,666	10	8			
60 waggons, at Rupees 400 each	24,000	0	0			
Maintenance and repairs, 25 per cent.	6,000	0	0			
Sundries	485	1	11			
				67,000	0	0
(b.)—Boats.						
6 sheet-iron boats with tackle, etc., at Rupees 2,000 each ...	12,000	0	0			
1 four-oared rowing boat	1,500	0	0			
2 pair oared do., at Rupees 800 each	1,600	0	0			
Maintenance and repairs, sundries, etc....	3,900	0	0			
				19,000	0	0
(c.)—Tools.						
Rock-cutting tools for 300 men, at Rupees 5 per man... ...	1,500	0	0			
Earth-work tools for 900 men, at Rupees 3 per man	2,700	0	0			
Carpenters' and Smiths' tools, workshop fittings, etc.	3,000	0	0			
Maintenance and repairs, 25 per cent.	1,800	0	0			
				9,000	0	0
(d.)—Lifting and hauling apparatus.						
4 1-ton cranes, at Rupees 850 each	3,400	0	0			
1 small pile-driving machine	800	0	0			
2 6-ton lifting and traversing jacks, Rupees 200 each... ...	400	0	0			
Maintenance and repairs, 25 per cent.	1,150	0	0			
Rope, chains and sundries	2,250	0	0			
				8,000	0	0
(e.)—Concrete-making apparatus.						
2 concrete-making machines, at £265 each	5,300	0	0			
1 stone-breaking machine, at £190	1,900	0	0			
Carriage from London to the Perryaur, 12 tons, at Rupees 85 per ton	1,020	0	0			
Maintenance, repairs, etc.	1,780	0	0			
				10,000	0	0

Tools, Plant, and Machinery.—(Concluded.)

	RS. A. P.	RS. A. P.
(f.)—Apparatus for raising water.		
2 thirty-horse power turbines, with pumps for raising 150 cubic feet per minute, at £480 each	9,600 0 0	
700 feet 15-inch delivery and suction pipe, at £0-16-6 per foot.	5,725 0 0	
1,200 feet 11-inch discharge pipe, at £0-11-0 per foot ...	6,600 0 0	
Bolts, bends, etc.	900 0 0	
1 fifteen-horse power turbine, with pumps for raising 75 cubic feet of water per minute, £280	2,800 0 0	
360 feet 11-inch delivery and suction pipe, at £0-11-0 per foot.	1,980 0 0	
600 feet 8-inch discharge pipe, at £0-7-4 per foot	2,200 0 0	
Bolts, bends, etc.	300 0 0	
Carriage of 120 tons from London to the Perryaur, at Rupees 85 per ton	10,200 0 0	
Fixing	4,000 0 0	
Repairs, maintenance, etc.	5,695 0 0	
		50,000 0 0
Total for Tools, Plant, Machinery, etc...	....	1,63,000 0 0

Distribution of the above charges.

—	(a.)	(b.)	(c.)	(d.)	(e.)	(f.)	Total.
	RS.	RS.	RS.	RS.	RS.	RS.	RS.
Dam and Culvert	49,000	19,000	4,600	7,000	10,000	......	89,600
Escape	16,000	......	3,400	1,000	......	......	20,400
Cutting	2,000	......	200	......	......	......	2,200
Road	......	......	800	......	......	......	800
Silting apparatus	......	......	......	......	......	50,000	50,000
Total...	67,000	19,000	9,000	8,000	10,000	50,000	1,63,000

Abstract Estimate for Head Works.

	RS.
I.—Silting apparatus	94,000
II.—Dam and Culvert	7,87,000
III.—Escape	3,80,000
IV.—Cutting through Water-shed...	56,000
V.—Road	1,40,000
VI.—Buildings...	75,000
VII.—Establishment	38,000
VIII.—Preliminary expenses	30,000
Total...	16,00,000

HAMPTON COURT,
14th November 1870.

(Signed) J. PENNYCUICK, Captain, R.E.,
Executive Engineer.

MEMORANDUM.

IN the project for the diversion of the Perryaur, forwarded by me on the 14th November, it was proposed to place the top of the dam at 205 feet above datum, and the crest of the escape at 174 feet, which would make the ordinary level of the

lake about 163 or 164 feet. These levels were chosen not only as being the most economical, but chiefly as allowing the work to be executed in the least possible time, as the time required for the construction of the escape and dam would be about equal.

2. I have since learnt that it is in contemplation to fix the ordinary level of the lake at about 200, which would bring the escape crest to 210, and the top of the dam to 240. In this case it would, of course, be necessary to build the dam on site No. 3, not, as proposed by me, on No. 2.

3. The cost of the escape in this case would not differ materially from that of the upper site at the 174 feet level.

4. The dam would contain 3,486,800 cubic yards of earth, of which 2,017,300 could be executed by silting, the remainder having to be done by manual labour.

5. In my estimates the cost of the earth-work (by manual labour) has been taken at 8 Annas per cubic yard, but this would be greatly increased if the dam had to be raised to 240 feet, owing to the increased distance from which the earth would have to be brought.

6. I believe I shall not be over-estimating the cost in adopting the following rates :—

Up to 180 feet	8 Annas	per	cubic	yard.
From 180 to 210 feet	10 „	„	„	
From 210 to 240 „	12 „	„	„	

7. From these data it is found that the cost of the earth-work of the dam would be Rupees 9,99,800 against Rupees 3,68,000 for the 205 feet dam on site No. 2.

8. In addition to this there would be an increase of 119 feet in the length of the culvert; the dam being thicker at the base and longer at the top, the area of stone revetment would be greater, and more ground would have to be cleared for the excavation of earth. These, with minor items, would add a further sum of about Rupees 70,000 to the cost of the dam.

9. The gap in the water-shed ridge would require a dam with a maximum height of 70 feet, and this would cost Rupees 1,70,000 against Rupees 56,000, the estimated cost of the cutting and sluice dam for the lower level.

10. The charges for contingencies, repairs, and maintenance of buildings, tools and plant, and for establishments, would also be largely increased, and altogether the cost of the head-works would be raised from Rupees 16,00,000 to Rupees 26,00,000.

11. The additional amount of labour required (allowing for materials, tools, etc.,) is nearly that of 1,200 coolies for 1,000 days.

12. In my calculations I have assumed 1,200 as the greatest number of coolies likely to be available for work at one time; the extra labour required will therefore be that of our whole available force for 1,000 working days, that is, for five seasons; this involves a postponement of the completion of the works for five years, and a sacrifice of revenue to the amount of 27½ lacs of Rupees.

13. The sole advantage to be gained by this raising of the lake level is the storage of more water during floods.

14. The quantities stored between the normal level of the lake and that of the escape crest would be—

For the 200 feet level	26,711 cubic yards.
For the 164 feet do.	39,008 „ „

Between the normal lake level and the maximum level during an excessive flood—

For 200 feet	1,06,927 cubic yards.
For 164 feet	77,020 „ „

That is to say, that the higher level would allow 12,397,000 cubic yards more to be thrown into the lake before any water passed over the escape, and that during an excessive flood, such as may perhaps be looked for once in twenty years, the higher level will waste 29,807,000 cubic yards less than the lower one.

15. For freshes smaller than that given in my Table No. 4, the one level would be as good as the other.

16. We have at present only one year's observations of the actual discharge of the river; during this year there was only one flood which would have passed over the escape for the lower level, and in this case the saving of water would have been the amount stated above (29,807,000 cubic yards). In ordinary years such a flood as this would not be likely to occur, but there might be two or three smaller ones. It is probably taking a high estimate to say that in an average year the amount of water saved by the use of the higher level would amount to 30 millions of cubic yards.

17. The effect of this increased storage will merely be that the lake will take a little longer in falling to its proper level after a flood; that is, that the high discharge through the cutting produced by the rise of the lake will last a few days longer with the larger lake than with the smaller one. This discharge varies from 675,000 cubic yards per hour at escape crest level to 1,100,000 at maximum flood level (190 feet), and is probably considerably more than the channels from the Vigay and Sooroolly (neither of which rivers is likely to be very low when the Perryaur is in flood), can carry off; any addition to it, or increase in its duration, will therefore merely cause more water to pass down the Vigay into the sea, where it will be as much wasted as if it went over the escape into the Perryaur.

18. In point of fact, the effect of raising the lake level from 164 feet to 200 feet would seem to be this: that in an average year some 30 millions cubic yards of water will go down the Vigay into the Bay of Bengal instead of down the Perryaur into the Arabian sea—a somewhat inadequate return for $37\frac{1}{2}$ lacs of Rupees.

19. I have hitherto said nothing about the increased difficulty (as distinguished from cost) of constructing a dam 240 feet high; but this is a point which cannot be overlooked.

20. I believe the 205 feet dam proposed by me to be thoroughly practicable, but to be very near the maximum limit. If the time required for the construction of the escape could be reduced, I should be very willing to lower the levels five or ten feet; but I should be very doubtful of the wisdom of raising them. All the

difficulties to be encountered increase so much with any increase in the height of the dam that I question very much whether a dam 240 feet high would ever be completed at all.

21. I should certainly be extremely unwilling to have anything to do with its execution, while nothing would give me greater pleasure than to be employed in carrying out the scheme proposed in my former report.

HAMPTON COURT PALACE, (Signed) J. PENNYCUICK, Captain, R.E.,
30th December 1870. *Executive Engineer.*

No. 72. ORDER THEREON, 4th May 1871, No. 1,236.

IRRIGATION, No. 10.

ORDERED that the Note by the Chief Engineer for Irrigation, with the papers accompanying it, be communicated to Mr. R. Smith.

2. His Excellency the Governor in Council has noticed with satisfaction the care with which Captain Pennycuick has drawn up his report and the estimates connected with the head works of the Perryaur project, but His Excellency regrets that, whether from misconception on his part of the terms upon which this work was entrusted to him, or from his supposing that what he had seen in England warranted a departure from his instructions, he has worked out a scheme differing materially from that required. By so doing he has much reduced the value of his labours.

3. The Government authorize the payment to Captain Pennycuick of £50, and the Controller of Public Works Accounts will be instructed to obtain and transmit to that officer a bill for that amount, and he will report to what head of charge the cost of the bill should be debited.

(True Extract.)
(Signed) J. CARPENDALE, Colonel, R. E.,
Secretary to Government.

To R. Smith, Esq.
,, Captain J. Pennycuick, R.E.
To the Controller of Public Works Accounts.
,, Acting Chief Engineer for Irrigation.
,, ,, Superintending Engineer, 8th Division.

Exd. S. T. Augustin.

4 May 1871 47

Read the following papers :—

No. 56.

No. 71. *Note by the Chief Engineer for Irrigation.*

In G. O. of the 12th May 1870, No. 1,236, the preparation of the designs and estimates for the Perryaur Project head works was entrusted to Captain Pennycuick, who was at the time about to proceed to England on account of his health, and this Officer has transmitted a Report, dated 14th November 1870, together with estimates amounting to Rupees 16 lacs, tables, and plans illustrating this part of the project. My examination of the papers has unfortunately been much delayed owing to the plans having taken nearly two months to get to Chetterpore, and back to Madras, by banghy.

2. Captain Pennycuick has gone into the subject in a very careful manner, but he has unfortunately not acted upon the decision which was come to with regard to the way in which the freshes in the Perryaur were to be passed down the river, during the construction of the embankment, consequently much of the time which this Officer has devoted to the preparation of the estimates and to detailed calculations, has been thrown away. After the construction of a culvert under the bund had been fully discussed and considered, as one means of providing for the discharge of the water, it was decided that a tunnel through the hill spur, forming the right abutment of the bund, would be the best and most economical arrangement, taking into account the waterway required for avoiding risk of accident to the embankment while under construction. The area of waterway to be allowed was somewhat under 2,000 square feet, 1,666 square feet being that required for passing the estimated maximum discharge of 75,000 cubic feet a second, or 10 millions of cubic yards an hour, with a velocity of 45 feet a second. The length of the tunnel was supposed to be about 330 yards, and its cost about 7 lacs of rupees. The circumstances which induced Captain Pennycuick to design and estimate for a culvert are given in paragraphs 41 to 48 of his report, and the considerations which led to the particular dimensions he has selected are contained in paragraphs 49 to 58; it will be seen that he has proposed to carry out the work in an entirely different manner to that intended in the instructions furnished to him; for, whereas in these the whole of the water was to be passed through the tunnel, and the bund was to be thrown entirely across the river after the completion of the tunnel, Captain Pennycuick proposes to leave a gap in the first instance, and to arrange to close this, after the flanks of the bund have been thrown up, to a height of 150 feet, or a little more, in 60 days (paragraph 57). Moreover, instead of a tunnel, the length of which was to be in excess by 12 feet of the width or thickness of the bund, the culvert has been designed with a length of 658 instead of 990 feet, and this alteration, together with the reduction of the waterway from 2,000 to 649 square feet, has diminished the cost from rough estimate of 7 lacs for a tunnel to the amount, Rupees 2,70,000, allowed by Captain Pennycuick for a culvert. Whatever alternative arrangements this Officer might have himself thought proper to advocate, his first duty was to design and estimate for the works in accordance with his instructions; any suggestions he

	RS.
Culvert	2,15,753
Tools and Plant	30,000
Sundries	24,247
	2,70,000

might have added would have received every attention. As it is, after waiting for many months, some of the information expected has not been furnished, but, in lieu of it, something which was not wanted has been given.

3. It will be noticed that, per square foot of waterway of culvert of two-thirds the length of that of the tunnel, the cost would be Rupees 416, equivalent, for the greater length, to 624 Rupees; that of the tunnel would be Rupees 350 per square foot.

4. Highly valuable as is Portland cement, it seems to me that there are risks which Captain Pennycuick has hardly taken into account. It is a material which must be kept perfectly dry; its quality varies considerably; it might or it might not do to use a concrete containing only one-ninth of its bulk of cement, and, lastly, the construction of piers and arches in this material would require some practical experience before it would be safe to introduce it at a great work of this kind.

5. Captain Pennycuick's proposals to use the surplus water for the purpose of raising a supply to a level which will admit of silting being carried on for the upper part of the bund are worthy of consideration. In Estimate No. IX. he gives the cost of the machinery required for raising $2\frac{1}{2} + 2\frac{1}{2} + 1\frac{1}{4} = 6\frac{1}{4}$ cubic feet a second as 50,000 Rupees, but it may be noticed that the allowance of piping seems to be much in excess of what would be necessary. Mr. R. Smith will be able to determine approximately, from the information given, what sum would be needed on this account. In Estimate I. the cost of the silting channels is entered at 44,000 Rupees in addition to the machinery already referred to; it may be noticed that of the Rupees 11,441, allowed for Portland cement concrete for the dams at the heads of the silting channels, only from one-third to three-eighths would be required for rubble masonry, a material quite suitable for the purpose; the rates for the earth-works also, *vide* Data V., are probably much higher than will be required.

6. The arrangements at the water-shed, referred to in paragraphs 115 to 118 of the Report, would not do at all. The maximum quantity of water required for irrigation in Madura will be about 1,955 cubic feet a second, whereas Captain Pennycuick would send into the Surulyaur 1,103,000 cubic yards an hour, or $8,272\frac{1}{2}$ cubic feet a second, and this would, first, swamp the country; secondly, occasion a great waste of water; thirdly, leave the canals in Madura without any adequate supply during a great part of the irrigation season; there must be no waste except in extraordinary freshes in the Perryaur, and then the surplus should go down the Perryaur, and not across the water-shed. The regulation at the water-shed should be complete, and the water required, and no more, should be passed through the sluices at that point. The arrangements required for the utilization of nearly the whole supply of the upper part of the Perryaur have been sketched out in the note above referred to. Mr. R. Smith has since stated that he thinks the requisite amount of storage can be secured at a lower level by tunnelling under the water-shed instead of cutting through it, and thus making the lake water for some depth below 155,* the intended sill of the cutting, available and if this can be economically accomplished the alteration will be advantageous. The arrangements are being worked out in detail.

Vide paragraph 12 of Note in G. O., 9th November 1870, No. 2,680.

* Captain Pennycuick has taken 157 in his Report, paragraph 61.

7. Captain Pennycuick's data have been carefully prepared, but the rates therefrom deduced will admit of considerable reduction. It will not be necessary to pay coolies 8 Annas a day; when they are sick it will suffice to give them their rations, and it would be a premium on idleness to pay them under such circumstances 4 Annas a day; the per-centage of sick, namely, 120 out of 1,120, may be allowed to stand, though I hope it will be considerably less. The cost of silting is, exclusive of that of the channels and machinery, put at 1 Rupee for 12 cubic yards; 20 cubic yards the rupee would be a safe and moderate estimate, and the reduction in the rate of cooly hire would make it approximate to this.

No. I.

8. In connection with the proposition, which I made in October last, for increasing the capacity of the lake at the Perryaur and making it the storage reservoir, I have received from Captain Pennycuick a demi-official memorandum, dated 30th December 1870, pointing out what he deems the objections to such a modification. Some of these objections have more or less force, but his estimate of the xpense of adding 39 feet to the depth of water appears to me based on rates which quite inadmissible. In the first place, if water be artificially raised for silting it uld add not very greatly to the cost to lift it some 40 or 50 feet higher, or even re, seeing that the power, surplus water, costs nothing. In the next place the rates earthwork, executed by means other than silting streams, might, if the soil were carried on coolies' heads, mount up as supposed by this Officer; but then no one would dream of so carrying it, and the cost per cubic yard with a tram would be no more, or but little more, at the higher than at the lower level, seeing that in each case the trams would be laid at a gradient, and start from above the level of delivery. Captain Pennycuick has overlooked the whole object of raising the lake surface, which is the securing of storage sufficient for the land to be irrigated. A certain amount of storage will be necessary; what that amount should be will be worked out by Mr. R. Smith more carefully than was done by me in the rough sketch of October last, but, whatever it may be, it is essential to the success of the project. It will be provided on a low level if possible, but, if this be not practicable, it must be obtained at a high level. Captain Pennycuick's memorandum will be found appended to his report.

9. I beg to recommend that these papers, with the plans received with the report, be transmitted to Mr. R. Smith, who will find much of value in them, though much of the detail is inapplicable to the circumstances of the project as now ascertained.

10. Captain Pennycuick has forwarded a bill for £41-18-0, being Mr. Stanford's charge for copying and mounting the plans, and he has also paid £0-12-6 for having the report copied. He mentions likewise that he was put to some expense in visiting Mr. Stanford's office for the purpose of supervising the plans. Had Captain Pennycuick carried out his instructions, it might have been proper to acknowledge his services by a considerable payment on account of the time devoted by him to this work; as it is I would recommend that he be paid

	£	s.	d.
The amount of Mr. Stanford's bill	41	18	0
Do. of charge for copying report	0	12	6
For travelling expenses	7	9	6
	50	0	0

Plans Nos. 5, 6, and 7 are useless; all the rest will be of value, although some of them will require modification.

FORT SAINT GEORGE, (Signed) J. MULLINS, Major, R.E.,
28th February 1871. *Chief Enineer for Irriation.*

No. . From Captain J. PENNYCUICK, R.E., Executive Engineer on special duty, to the Chief Engineer for Irrigation, Madras, dated Hampton Court Palace, Middlesex, England, 14th November 1870.

I HAVE the honour to forward, herewith, the plans and estimates of the head works of the project for the diversion of the Perryaur, entrusted to me by O. G., No. 1,236, of the 12th May 1870, together with an explanatory report.

2. It was impossible for me to send these papers sooner, as my health has been so uncertain since my departure from Madras that I have not been able to work regularly until within the last few weeks, and you will readily understand that the amount of calculation to be gone through has been considerable.

3. I have endeavoured to make the report as complete as possible, so as avoid any necessity for reference to former papers upon the same subject.

4. I enclose Messrs. Stanford and Co.'s account,* amounting to £41-1[illegible] for copying the plans; I have also p[illegible] the sum of £0-12-6 for the copying of my report. In addition to this I have been put to some charge in the matter of travelling expenses, as the copying of the plans had to be done in London, and I have had to visit Messrs. Stanford and Co.'s office frequently, in order to superintend them; but I am unable to state exactly what this expense has been, as the journeys in question have been so mixed up with those made on my own affairs that I cannot separate them.

* Paid by me.

5. I shall be glad to be informed of any orders that may be passed by the Madras Government in connection with this project.

Report on Project for the diversion of the Perryaur.

THE project for which plans and estimates are now forwarded, is for the diversion of the Perryaur river from its present westward course into the valley of the Vigay, for the irrigation of part of the Madura District.

2. The present state of the district cannot be better described than in the words of Captain Ryves.†

† Introduction to Report on Perryaur Project, 7th August 1867.

"The principal division of the Madura District, consisting of the three Talooks of Madura, Meyloor, and Tirumungalum, is a strip of country running north and south; its eastern boundary marching with the adjoining Zemindary estates of Shevagunga and Ramnad, and on the west separated from the Dindigul division of the district by the mountains and jungle which extend almost continuously, from Nuttam on the north to Strivilliputur on the south, where they run into the general range of the Western Ghauts, which here separate British territory from the Travancore country.

"Its area, excluding uninhabited mountain and jungle, is about 1,200 square miles, with a population of very nearly half a million.

"The Vigay river, passing through the only opening in the hills which form the western boundary, flows across the strip, the length of its course within the limits above defined being about 33 miles. In this length several river channels are taken off, most of them to fill tanks during the short and uncertain period of Vigay freshes. The principal channels are the Vadakurry, the Tenkurry, the Nellayoor, and the Madacolum.

"Vada," north.
"Ten," south.
"Kurry," bank.

"The two first have the advantage of anicuts across the river at their heads, the other two as well as all the other channels, are supplied by means of temporary spurs (made of grass and sand "corumboos") run out into the river. The numerous tanks supplied by the channels were many of them first-class reservoirs originally, but are now so silted up as not to be capable of storing much more than half the quantity of water they were designed to hold; they occupy a great deal of valuable land, and, in the attempt to get as much water as they require, the ryots of one tank frequently cause injury to their neighbours above them by damming up their escape calingulahs and flooding land by the extended water-spread.

"The tanks having become shallow in proportion to the area of the water-spread, there is enormous waste of water by evaporation. I calculate that this waste amounts to at least 30 per cent. of the water stored.

"The character of the Vigay makes the tank system essential. For some reason or other the quantity of water received into the channel of the river bears a very small proportion to the rain-fall on its catchment basin; the average annual rain-fall at Pereacolum and Madura is 32 and 41 inches respectively. In the Cumbum valley (where no register has been kept) it is at least as much* as at Pereacolum; in the Wursanaad valley it is probably less. Taking it at only 33 inches over the whole catchment basin above the Peranny, it would amount to 3,600 millions of cubic yards per annum, and supposing that only one-third of this found its way into the streams and rivers, so as to be available for irrigation, there would be more than enough (with due allowance for the enormous waste on tanks) for three times the extent of paddy crop now raised.

* I should say 40 or 50 per cent. more throughout the valley of the Sooroolly and Teviar.—J.P.

"Yet it is affirmed on good authority that in an average year not a drop of Vigay water reaches the sea; but, I think, this is hardly sufficiently well established to be accepted as the fact. My belief is that sufficient water for more than double the present area of irrigation *does* flow down the Vigay, but that three-fourths of the annual supply passes down the river at three times the rate at which all the channels together can draw off the water from it: so that, if the big freshes could be detained so as to be spread over, say, 60 days, instead of running off at three times the rate in 20 days, it would be found that there would be water enough (if the tanks could contain what it would be necessary to store) for double the present area of rice crops.

"However this may be, there is no doubt as to the main fact that the supply of water obtained from the Vigay is so precarious and scanty that even in good seasons the paddy crop barely covers 22,000 acres annually, although the existing channels and tanks command land enough, and have sufficient hydraulic capacity

for the irrigation of fully double that extent of crop if only a sufficient supply of water, delivered at a regular moderate rate, be ensured.

"This Vigay irrigation is situated in the Madura Talook, the middle one of the three named above. In the Meyloor Talook there is but one river, and that but a small stream, at its northern extremity, under which a small extent of land receives a good and certain supply. All the rest of this talook is dependent for irrigation on the local surface drainage, stored in small shallow tanks, the majority of them being mere ponds. Situated, as all the land of this talook is, within a few miles of the water-shed, there are no well-defined streams; the Allighiny hills form a dyke, turning all the hill streams to the north and south round the flanks of the talook.

"The north-east monsoon, from which this talook receives what rain it *does* get, is very uncertain so far south and inland, and the mountains to the west of it (the streams from which as above shown do not flow through this talook) no doubt draw away from it a considerable proportion of the rain cloud which may have travelled so far.

"Under these circumstances it is not surprising that agricultural operations are but seldom rewarded by a good crop. If the ryot is so fortunate as not to find the ground as hard as brick at the ploughing season, the chances are that rain necessary to bring the crops to maturity will not fall at the expected time.

"And the cultivation of wet crops is hardly a less precarious business, failure being attended with greater loss, and success attained generally at much expense of labour and money on raising water from wells and pools.

"Almost every alternate season is one of scarcity in this talook, and when an exceptionally dry year occurs there is severe distress, and the population is thinned by death and emigration. In 1861-62, and again last year,* it suffered severely in this way.

* Written in 1867.—J. P.

"If the water-supply in the Vigay were sufficient, half of Meyloor could be irrigated from it."

3. The idea of increasing the water-supply of the Vigay, by turning into it some of the streams which now flow through the hills to the Western Coast, is a very old one, and more than one attempt has been made to give it practical shape.

4. There are in existence the remains of an old dam across the Sairveyellar one of the minor tributaries of the Perryaur, which appears to have been actually in operation at some former date, and in 1838 an attempt was made to construct a similar dam across a somewhat larger stream, the Chinna Mollyaur, by which the Sairveyellar joins the Perryaur. Considerable progress was made with this work, the remains of which are still clearly visible, but for some reason or other it was abandoned, and no attempt has since been made to resume it.

See Plan No. 1.

5. So long ago as 1808, a proposal was made for the diversion of the Perryaur itself, but does not appear to have received very much consideration, and although the idea has been taken up from time to time since that date, it is only within the last few years that it has been seriously considered with a view to active operations.

6. In 1867 Captain Ryves submitted a detailed project, with plans and estimates, for the diversion of the Perryaur into the valley of the Sooroolly, a tributary of the Vigay, and for the distribution of the water-supply thus obtained in the three talooks of Madura, Tirumungalum, and Meyloor.

O. G., No. 3,521, 14th November 1867.

7. It was found, however, that the information at Captain Ryves' command was defective on some important points, and it became necessary to make further investigations into the nature of the country and the circumstances under which the work would have to be carried out.

8. These investigations have been actively carried on during the last two years, and their result is embodied in the papers now submitted to Government. Circumstances appear to require some modifications in the details of the arrangements proposed by Captain Ryves, but in essential points the project remains the same as when first submitted by him.

9. An examination of the map will show that the project consists of two distinct parts, entirely independent of one another in an engineering point of view, though connected financially, namely, the works for diverting the course of the stream and those for the distribution in the Madura District of the water-supply thus obtained.

10. This report deals only with the first part, or head works. Concerning the latter it is sufficient to remark here, that according to Captain Ryves' calculations, which are fairly borne out by the results of our observations during 1869-70, the water-supply of the Perryaur will be sufficient for the irrigation of 149,000 acres of paddy, and will yield a net revenue of Rupees 5,50,000 per annum.

11. The cost of the head works is now estimated at Rupees 16,00,000, so that even if the distribution works cost as much as Rupees 15,00,000,* the revenue would still be nearly 18 per cent. on the cost of the project.

* They were estimated by Captain Ryves at Rupees 5,58,000 only, but this estimate was very hastily made, and there is no doubt is a good deal under the mark.

12. The Perryaur river rises in the hills which separate the drainage basins of the East and West Coasts of Southern India, and, after flowing for some distance with a course generally from south to north, it turns in about north latitude 9° 30′ to the west.

At the angle formed by this change, of course, it receives the Perya Moollyar, which with its tributary, the Chinna Moollyar, brings down the drainage of a considerable tract of country to the north and east of the main river.

13. Running northwards, from the junction of the Perya Moollyar with the Perryaur, is a nearly straight valley, formed in succession by the streams of the Perya Moollyar, the Chinna Moollyar, the Sairveyellar (a tributary of the latter), and a small water-course falling into the Sairveyellar.

See Plan No. 1.

14. At the head of this valley is a remarkable depression in the water-shed ridge, the lowest point of which is about three miles and a half due north of the nearest point of the Perryaur, and 170 feet above its bed at the mouth of the valley.

It is proposed to turn to account the facilities offered by this depression for throwing the waters of the Perryaur over the water-shed ridge into the valley of the Sooroolly.

15. The total difference of level, about 170 feet, may be overcome either by raising the water of the Perryaur by means of a dam, so that it may pass over the ridge; by cutting through the ridge with a dam merely sufficient to close the present valley of the Perryaur, or by a combination of the two processes, overcoming part of the height by raising the level of the stream and part by cutting through the water-shed ridge.

16. The first and most essential points to be fixed are, the site of the dam for closing the Perryaur valley and the proportions of height to be overcome by dam and cutting respectively; in other words, the height of dam and depth of cutting.

17. As the discharge of the Perryaur when in flood is so great that it would cause dangerous inundations if the whole of its water were thrown into the Sooroolly, it becomes necessary to provide, in connection with the dam, an escape or waste weir, by which the surplus water, beyond that which it is desirable to throw into the Sooroolly, may be passed back into the valley of the Perryaur below the dam; the necessity for the construction of such an escape will have an important influence in determining the choice of a site for the dam.

18. An examination of the ground in neighbourhood of the junction of the Moollyar and Perryaur valleys shows that there are three sites (marked on Plan No. 1 as No. 1, No. 2, and No. 3, respectively,) on which a dam may more or less conveniently be constructed.

19. The uppermost of these, or No. 1 site, was that chosen by Captain Ryves on account mainly of certain facilities supposed to be offered for the construction of an escape by the saddles A and B; but the information at Captain Ryves' command was at that time very defective, and it is probable that he would not have chosen this site had he been better acquainted with the details of the nature of the ground. Concerning this site it is sufficient to remark here that a dam 190 feet high would contain as much earth as one 205 feet high on site No. 2 (involving 15 feet more cutting), while, owing to the configuration of the ground, only about one-half of the whole amount of earthwork could be executed by the silting process (which saves five-sixths of the cost of execution by manual labour) against five-sixths which can be so executed at the lower site.

20. There are other minor objections to No. 1 site, but this one is final.

21. Comparing the other two sites, it appears that a dam at No. 3 will contain about one-tenth less than one of the same height* at No. 2, and that the nature of the bed of the river is in some respects slightly more favourable for the control of the stream during the construction of the dam; the facilities for executing the earthwork by silting are about equal, the balance being, if anything, rather in favour of No. 2.

* Within the limits with which we have to deal.

22. On the other hand, there is at No. 2 a saddle, which may be used for an escape, about 205 feet above the present surface of the river; whereas at No. 3 the

only saddles available for this purpose are at more than 240 feet above the river. The lower site, therefore, involves such a very great expense in lowering one of these saddles to form an escape, or in raising the dam in order to avoid this, as will far more than counterbalance the slight advantage offered by the diminished quantity of earth required for a given height of dam.

23. It thus appears that the site marked No. 2 (with the saddle C for an escape) is the most favourable that can be found for the dam.

24. If any given level be assumed for the sill of the cutting through the water-shed, (or what comes to the same thing, for the ordinary surface level of the lake, formed by damming up the river,) the height of the crest of the escape will depend upon the breadth and discharging capacity of the cutting, the area of the lake, and the limit which it may seem advisable to fix as a minimum to be reached by the discharge of the river before any water is allowed to flow to waste over the escape.

25. Again, the level of the escape crest being determined, the height of the crest of the dam above it will depend on the width of the escape, the area of the lake, the discharge of the river during a great flood (which together will determine the maximum level to which the lake will rise), and the clear height which may be considered necessary to allow to the dam above the highest surface level of the lake.

26. It is a fortunate circumstance that, during last year, a flood occurred which there is clear evidence, from the state of the river banks, was greater than any which had passed down for many years. The levels, velocities, and discharges of the river were constantly noted during the whole progress of this flood, and we are thus in a position to form a very good idea of the maximum effort to which our works are likely to be exposed, without the necessity of using an imaginary table of discharges based upon a certain rate of rain-fall discharged by the river for a given time.

See Tables I., V., and VI.

27. The principles on which the relative heights of the sill of cutting, crest of escape, and top of dam have been calculated, are—

See Table IV.

1st.—That no water should pass over the escape until the discharge of the river exceeds an "ordinary big fresh."

See Table V.

2nd.—That the maximum discharge of the cutting during an excessive flood should not greatly exceed one million cubic yards an hour (7,500 cubic feet a second).

3rd.—That the top of the dam should be 15 feet clear above the highest flood level of the lake.

28. If any level be assumed for the sill of the cutting, those of the crest of escape and top of dam will become a matter of calculation, depending on the widths of the cutting and escape and area of the lake, and it is obvious that these

elements are susceptible of an almost infinite number of combinations; the levels recommended by Captain Ryves were—

Sill of cutting	129 feet above datum.*
Breadth of cutting ...	40 feet.
Crest of escape	146 feet above datum.
Top of dam	166 feet above datum.

Length of escape about 600 feet.

* The datum level of these surveys is the top of a rock in the middle of the river at No. 1 site, and very fairly represented the mean summer level of the river surface at that point and for nearly a mile lower down.

29. Captain Ryves contemplated executing the whole of the earthwork in the ordinary way by manual labour, but the introduction of the "silting process" by Mr. McIvor, has so diminished the cost of this work as to render it advisable to raise the dam and effect a corresponding saving in the amount of cutting required.

29. After a large amount of very careful calculation, I have come to the conclusion that the following proportions will be the best:—

Level of cutting sill	... 157	feet above datum.
,, escape crest	... 174	,, ,, ,,
,, top of dam	... 205	,, ,, ,,
Width of cutting at bottom	30	,,
Length of escape ,, ,,	400	,,

30. It does not appear necessary to detail all the calculations by which these results have been arrived at, but I may mention that if all the levels were reduced 5 feet, we should save in the construction of the dam about 150,000 cubic yards of earth, of which 30,000 would be from the part executed by silting and 120,000 from that executed by manual labour. Against this there would be an additional 60,000 cubic yards of rock to be removed for the formation of the escape, and an addition to the cost of the cutting of above Rupees 20,000, besides other minor alterations, the general result being that the whole work would cost about Rupees 45,000 more than the present estimate. There would be no saving of time; indeed, it is possible that the large amount of blasting required for the escape might render another season's work necessary.

31. On the other hand, if all the levels were raised 5 feet, the additional earthwork required would be about 30,000 cubic yards by silting and 132,000 by manual labour; the reduction in the quantity of rock to be removed from the escape would be about 44,000 cubic yards, and in the cost of the cutting about Rupees 8,000.

32. If the same rates as those adopted in the present estimate were taken, this alteration would cause no appreciable increase or reduction in the total cost of the works; but the rates for earthwork would probably be slightly increased, as the earth for executing the upper part of the dam would have to be brought from a greater distance; the time required for the completion of the work would be probably, though not certainly, increased by a season.

33. It appears then that the level chosen is the most favourable in an economical point of view, and also as regards the time required for carrying out the works, since the time required for executing the dam is about the same as that for forming the escape and cutting. If the levels are raised the dam would probably

take longer, and, if lowered, the escape and cutting would require more time. It is difficult to speak positively on this point, but I doubt whether we could command skilled (or at least semi-skilled) labour enough for the execution of more than 50,000 cubic yards of blasting in each season.

34. All the calculations from which the quantities of work to be done have been deduced are based upon careful and detailed surveys of the ground affected and actual examination of the depth of earth, with the exception of the relative proportions of rock and earth to be removed for forming the escape, which can only be considered as an approximation, circumstances having prevented a detailed examination of the saddle (C) being made before the close of the last season's work at the Perryaur.

35. The depth of earth on this saddle has therefore been assumed, the estimate being based on the depths known to exist on similar saddles in the neighbourhood which have been examined, and enough is known of the nature of the ground on this one to render it tolerably certain that the conditions assumed do not differ greatly from those actually existing, and that if there be any difference it would probably be that the depth of earth is greater than I have supposed.

36. In a memorandum, No. 95, of the 27th April 1870, Major Mullins remarks that should the rock be found at a lower level than I have been led to expect, he should be disposed to reduce the levels by 5 feet. I do not think this would be desirable; the reduction caused by the rock being found at a lower level than that which I have assumed, will at any rate not be great, and will be confined to a small area near the centre of the escape.*

* We know the position of the rock, a short distance east and west of the centre, as it appears in the beds of the water-courses.

Thus, although the actual cost of the escape, whatever may be the level of its crest, may be somewhat less than I have allowed, yet the relative cost of an escape at the 174 feet level and one at 169 feet will remain the same, and the arguments in favour of the higher level will apply equally, whether the rock at the saddle be found at 190 feet (as assumed) or a few feet lower.

37. The length which I have allowed for the escape crest is 400 feet. If it were made shorter there would be a reduction in the cost of the escape, but the dam would have to be made higher (or the escape crest lower) to allow for the increased depth of water which must pass over during a flood. If the escape crest were lengthened, the height of the dam might be slightly reduced, but the cost of the escape would be greatly increased.

38. Calculation of the relative cost for various lengths of escape crest shows that the length named, 400 feet, gives the best results.

39. Since the execution of the earthwork of the dam will occupy three or four seasons, it becomes necessary to provide for the discharge of the river during the progress of the work. It would be obviously impossible to pass (at any reasonable cost) the discharge of such a flood as that shown in Tables V. and VI. over the dam by means of syphons or any similar arrangement, and out of the question to allow it to flow over the earthwork.

40. We appear to have to choose between only two alternatives: a culvert underneath the dam, and a tunnel through the hill on one side of it, communicating with the river above and below, by open cuttings.

41. At the time that I left India, the latter course, which was first suggested by Colonel Orr, was believed to be the best, inasmuch as a masonry culvert would require a large amount of skilled labour, of which it was doubtful whether we could command sufficient to complete the culvert within a reasonable time, and would certainly cost much more than a tunnel of the same waterway.

42. Since I have been in England, I have had the opportunity of seeing Portland cement concrete used on a very large scale in marine works, and I am convinced that by the use of this material we shall be able to construct, in perfect safety, a culvert in less time and with the expenditure of far less local labour than would be required for a tunnel of the same capacity.

43. At Douglas, in the Isle of Man, this material is being used for the faces (not merely for backing or filling in) of the sea walls, and parts of the wall which I saw have been exposed for two years to the action of the sea without the very smallest injury being preceptible. The steps of the landing quays are of this concrete, and after having been exposed between high and low water for two years to the full force of the sea, and to all the wear and tear incident to such a position, they are as clear and their edges as sharp as the day they were built.

44. At Port Erin, on the south-western coast of the island, the concrete is exposed to a test still more severe. There it is used in blocks of from 10 to 18 tons weight for filling in, without packing, cement, or arrangement of any kind, the space between piled framings for forming a breakwater; used, in fact, as *pierre perdue*. At this place I saw blocks which had been down between high and low water for two winters, and there was not the smallest sign of erosion or fracture on any of them; in fact, I should have been surprised to see the hardest stone in such a position so little worn.

45. In works of this nature, the concrete is not exposed to precisely the same action as in a culvert with water passing through it at a velocity reaching occasionally to perhaps 60 feet a second, but the whole action of the sea on one of the stormiest parts of the English coast* must expose it in another way to a far greater strain.

* The breakwater at Port Erin runs across part of the chord of a nearly semi-circular bay completely open to the south-west. Its main object is to afford a place of refuge to the numerous fishing-boats which ply about the island.

46. Mr. Powell, the Engineer to the Isle of Man Works, to whom I am indebted for much valuable information on this point, agrees with me that there would not be the slightest risk in using the Portland cement concrete for a culvert under such conditions as we have to deal with, and the question of safety being conceded, on other points the superiority of a concrete culvert over a tunnel is undeniable.

47. As to cost: at the rate of 10 Rupees per cubic yard for excavation in rock, the tunnel would cost a little less than a culvert of the same length and area of waterway; but the culvert, as will be explained hereafter,* need only be made to run under about two-thirds of the whole length of the dam, whereas the tunnel, with the open cuttings at its two ends, must be made sufficiently long to clear both faces of the dam when complete. This would cause the total cost of the tunnel to be considerably greater than that of a culvert of the same discharging power;

* Paragraph 60.

its construction would occupy certainly two and possibly three seasons, while the culvert could be easily completed in one, and, lastly, almost the whole cost of the tunnel will be expended in local labour, and chiefly in blasting, of which we have already a large amount to execute for the escape and cutting, whereas seventeen-eighteenths of the cost of the culvert* is for the price of the cement, the amount of local labour required being very trifling. This latter point is of the utmost importance, seeing how essential it is to reduce the quantity of local labour required as much as possible.

* See table of Data, No. IV.

48. For these reasons I have determined to recommend a culvert of Portland cement concrete, as the best means for passing the stream of the river under the dam during its construction.

49. It is necessary next to consider the dimensions to be given to the culvert.

50. There are two periods at which heavy floods may be looked for, namely, during the south-west monsoon, which may be said to close about the middle of July, and during the north-east monsoon, which may commence any time after the beginning of October and extend to the begining or middle of December. Small freshes may be expected, and great floods are not impossible, throughout the latter half of the year, but freshes of any magnitude will be very rare except during the periods named.

51. The capacity of the culvert must, therefore, be such that the remainder of the bed of the river being closed, a flood cannot rise to within 10 feet of the height to which a dam canbe carried in the period between the close of the south-west monsoon and the commencement of the north-east, or between the close of the latter and the end of the working season in February,† the period in either case being limited to about 60 working days.

† The extreme unhealthiness of the Perryaur country from March to June, renders it absolutely necessary to stop all work during these months. The working season is therefore limited to the eight months from July to February, or about 200 working days, at 25 days per month.

52. It is calculated that if the whole breadth of the river were closed at once, a dam with a top width of 20 feet, and front and rear slopes of 2 and 3 to 1 respectively, could be carried to a height of about 110 feet within the period named. The culvert must, therefore, have a capacity sufficient to prevent a great flood, such as actually occurred in November last, from rising to a height exceeding 100 feet.

53. To effect this the culvert would require a waterway of more than 2,000 square feet, and its execution would take probably two seasons; a tunnel of the same area would require four or five.

54. In order to reduce as much as possible the cost of the culvert and the time required for its execution, I propose to complete the dam on the flanks and over a portion of the bed of the river, before closing the centre of the bed, so as to diminish the length of the dam to be constructed in the limited period above named. This will enable us to carry the dam to a greater height between the two monsoons, and reduce the waterway required for the culvert.

55. The present width of the river bed varies from 116 feet at the upper end of the length covered by the dam to 206 feet at its lower end.‡ At the latter point the stream is very shallow, indeed half its bed is frequently dry even during December.

‡ The greatest width is a little above the lower end of the site, nearly 250 feet, but a good deal of this is taken up by rocks and huge boulders.

56. There would be neither risk nor difficulty in narrowing the aperture to a width of 120 feet, and leaving this space for the stream to flow through freely until the work on both flanks was carried up to its full height.

57. Over this space of 120 feet in length a dam with a top thickness of 20 feet could be carried in 60 days to a height of 150 feet, or perhaps a little more. The area of the culvert must, therefore, be such as to prevent a flood from rising to above 140 feet.

58. This will be effected* by giving to the culvert the dimensions which are shown on the plans, namely, three arches each of 9 feet span, and 20½ feet height up to the springing of the arches—total area of waterway 649 square feet.

* See Table VI.

59. The culvert might possibly be made smaller, as it is not likely that such a flood as I have anticipated will occur during the particular year in which the central portion of the dam is executed; still we know that such a flood has occurred and may occur again, and it seems best to provide against the greatest risk which may reasonably be considered possible.

60. The dam will have a front slope of 3 to 1, with a top width varying from 40 feet in the centre to 20 feet at each end; but, in order to reduce as much as possible the cost of the culvert, I propose to make it of sufficient length to carry a dam with a rear slope of 7 to 5 only; * this will leave an opening in the dam above and beyond the lower end of the culvert, which will have to be filled in after the culvert is closed on the completion of the remainder of the dam. There will be no dfficulty in making the rear slope of the dam stand at the inclination stated, and, as the water above the dam can never rise to a higher level than 140 feet so long as the culvert is open, the mass of this portion of the work will be amply sufficient for stability. Indeed the culvert might be made even shorter than I propose, but that the opening in its rear would then be more than we could be sure of being able to fill up in the period between the closing of the culvert and the end of the same working season.

* See Plan No. 7.

61. To repeat the principal dimensions of the various parts of the work:—

Level of top of dam	205 feet above datum.
Crest of escape	174 ,, ,, ,,
Sill of cutting	157 ,, ,, ,,
Top thickness of dam at centre ...	40 feet.
Do. do. at ends ...	20 ,,
Front or upper slope	2 to 1
Rear or lower do.	3 to 1
Length of escape	400 feet.
Bottom width of cutting	30 feet.

Culvert to consist of three arches, each 9 feet span, $20\frac{1}{2}$ feet high up to springing, and 25 feet to crown of arch; area of waterway 649 square feet, thickness above crown of arch $2\frac{1}{2}$ feet; total height $27\frac{1}{2}$ feet. Thickness of piers 4 feet, of foundations 5 feet, depth of foundations 4 feet. Length of culvert 658 feet.* Sill of culvert to be as near datum level as possible.

* This is somewhat more than the thickness of the dam at this level, as the formation of the river bank requires the culvert to be built somewhat obliquely to the general line of the dam.

62. The main outlines of the scheme being thus decided on, it remains to consider in detail the mode of carrying it out. It will be understood that the time mentioned in this report, as necessary for the completion of the works, is exclusive of that required for the execution of the road to the site of the dam, which is believed to be now in progress, and which must be completed before the actual execution of the works at the Perryaur can be commenced.† The working season, as already remarked, occupies from the beginning of July to the end of February.

† It would be convenient that the machinery required should be transported to the river bank at the end of the season before that in which the works are to be commenced, as the roads are likely to be in better condition for the transport of heavy loads in January or February than in July.

63. The first thing to be done is the commencement of the " silting channels" from the site of the dam to the Chinna Moollyar by the right bank of the Perryaur, and to the Arinashi stream by the left bank (see Plans 1 and 2); at the same time the excavation for the foundations of the culvert should be commenced, as well as the blasting away of the escape saddle.

64. As soon as the silting channel on the right bank reaches the Palgatchemadu stream, which should be by the middle of August at latest, the distance by the channel being only about 3,000 yards and the ground easy, the water of this small stream will be turned into it, so as to give a power for working the turbines‡ by which I propose to drive the machinery for the manufacture of concrete.

‡ These turbines will be afterwards required for raising water for silting; see paragraphs 90-92.

65. The Palgatchemadu stream has a drainage of about one square mile, and from July to November its discharge is not likely to be less than 3 cubic feet per second. The available fall from the silting channel is about 90 feet, and as a turbine does a duty of over 70 per cent., the available power at command for working the concrete machinery will be $\frac{7}{10} \times \frac{3 \times 60 \times 62\frac{1}{2} \times 90}{33,000} = 21\frac{1}{2}$ horse power nearly,‖ the power actually required being not more than 16.

‖ Which may be more than doubled at a very trifling cost, by storing water during the night for use during the day.

66. The concrete-making machine consists essentially of a hollow cylinder about 6 feet long and $3\frac{1}{2}$ feet in diameter, turning on its axis, which slopes from the horizontal at about 1 in 8. In the inside of this cylinder are four blades running its whole length and crossing (in section) about half the breadth of a chord of 125 degrees.

67. The materials for making the concrete, are inserted at the upper end of the cylinder, and are thoroughly mixed by being turned over and over by the blades as it revolves. At the same time by the longitudinal slope of the cylinder they gradually slide forward until they issue in a completely mixed state at its lower end, where they may be received at once into the moulds or frames for supporting the concrete until it is fully set.

68. The quantity which one machine will turn out is about 240 cubic feet in an hour, or 2,160 cubic feet in a day of nine hours. I propose to use two machines, which will enable us to execute all the concrete required for the culvert in less than 100 working days.

69. Wooden moulds or framing will of course be necessary for the piers and centering, which may be easily and cheaply constructed with bamboos, for the arches. The greater part of the culvert will be on the bank, quite clear of the river bed. A few feet at the lower end may have to run into the river, but the stream here is so shallow that in moderately dry weather there will be no difficulty in setting up the framing.

70. In order to avoid the labour of carrying the concrete to any great distance from the machines, I should propose to mount these on trucks, running on rails laid along the completed portion of the culvert walls, so that the machinery could be run forward as the work progressed.

71. The proportions of materials required for the concrete are given in the Table of Data No. IV. The sand and shingle can be obtained in unlimited quantities from the bed of the river, a short distance above the site of the dam, to which they will be brought in boats.

72. The stone will be obtained from that removed for the formation of the escape, and will be broken up by a machine driven by the same turbine as works the concrete machines.

73. The stone-breaking machine consists essentially of two powerful steel jaws, one fixed and nearly vertical, the other movable in a vertical plane on a pivot at its lower end. This jaw is moved by an eccentric, at each revolution of which it advances and recedes one-fourth of an inch. The distance apart of the jaws at the top is about three times that at the bottom. A stone being dropped in at the top slips down until it is stopped by the converging faces of the jaws; it is slightly broken by the next forward movement of the movable jaw, and the pieces slide down until again stopped, and so on until they are small enough to pass out at the bottom opening, the width of which is regulated according to the size to which the fragments are to be broken.

74. I have seen both these machines at work, and can testify to the simplicity of their construction, and to the ease and completeness with which they work.

75. Towards the end of the season, when the water in the hill streams begins to diminish, the construction of the dams for turning the Chinna Moollyar and Arinashi streams into the silting channels, will be commenced. It will be well here to give a brief outline of the "silting process" for executing earthwork, and of the extent to which it is proposed to adopt it at the Perryaur.

76. The essential requisites for carrying out this process are, a supply of earth at such a height above the place where it is to be used in a dam or embankment, as to allow it to be brought to that place at a gradient which should not be less than about 1 in 20, but may be as much more as possible, and a supply of water in such a position as to enable it to be passed through the earth quarries.

77. These requisites being obtainable, a small channel is made through the earth quarries to the site of the dam or embankment, and the water turned into it; the earth along the bank of the channel is loosened so as to fall into the water, by which it is carried down to the embankment in the form of thick mud. On

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arriving at the embankment, this mud being spread over a large surface the earth sinks to the bottom, and the water is drained off nearly pure, leaving the earth behind in the form of very fine silt, which in a short time hardens into a mass firmer and more homogeneous than could be obtained from any amount of manual labour.

78. The water thus does all the transport of the earth, and greatly aids in its excavation, the only labour required being that of a few men for watching the channels,* keeping them clear of stones, etc., (the channels themselves are mere notches, of which a cooly can cut a yard in a few minutes,) for making and keeping up a small bank by which the water is kept on the top of the main embankment until the earth is deposited, and a certain number for loosening the earth so as to allow it to fall into the silting channels. For this latter purpose I have allowed† one man for every 10 cubic yards. Where the soil is good a cooly would probably do 15 or 16 cubic yards in a day of nine hours, but about the Perryaur the earth, even at the best places, is a good deal mixed with roots and stones, and I do not consider that it would be safe to allow a greater quantity than that named.

* And at the Perryaur, for watching the main channels which bring the water to the site of the works. This is necessary to prevent injury to these channels from rain and other causes, above all from the elephants which infest this part of the country.

† See Table of Data No. II.

79. An examination of the plan (No. 4) and of the Tables of Quantities, Nos. I., II., and III., will show that the supply of earth in such a position as to fulfil the conditions required is not quite sufficient for the construction of the whole dam.

80. Up to 70 feet above datum all the earthwork may be executed by the silting. Above that level sufficient earth could be obtained to complete the dam up to about 150 feet; but as a certain amount of this can be brought to the dam at a much higher level than 150 feet, some indeed to the very top of the dam, I prefer to distribute the earth available for silting along the full height of the work (above 70 feet), executing a certain portion by silting, and a certain portion by manual labour, rather than to execute the whole of the lower part by the former process and of the upper part by hand. Moreover, this course does away with the necessity of puddling the face of the dam, which is not necessary where the silting process is employed, but would be required wherever the whole thickness of the dam was executed by manual labour.

81. In comparing Table of Quantities No. III. with Nos. I and II., it must be borne in mind that earth shown therein as available for any given level may be used at a lower one but not at a higher.

82. We have next to consider the possibility of obtaining water for transporting the earth which is found to be available for our purpose.

83. On the right bank of the Perryaur, the only streams of any considerable size within a reasonable distance of the site of the dam are the Chinna Moollyar, which joins the Perryaur about a mile and a quarter above the site, and the Nellecumputty stream, which joins it about four miles below. The latter stream, up to a considerable distance above its junction with the Perryaur, as well as the ground between it

See Plan No. 1.

and the site of the dam, has been carefully surveyed, but the result shows that the facilities offered by it for obtaining a water-supply are greatly inferior to those offered by the Chinna Moollyar. The channel for any given level would be considerably longer and the supply of water very much less. Indeed the greater part of the drainage of the Nellecumputty stream comes from so low a level that the stream itself is quite insignificant at 200 feet above datum. The Chinna Moollyar then is the only stream (on the right bank of the river) that can be made use of for the purpose under consideration.

84. At a level of about 132 feet above datum the Chinna Moollyar is joined by a small tributary, the Sairveyellar, whose valley has a slope much more gentle than that of the Chinna Moollyar itself; if the main silting channel were taken off from the latter above the junction of the two streams, we should require either a high aqueduct to carry the channel over the Sairveyellar (losing at the same time the water, about one-fourth of the whole, which it brings down) or a long channel to turn it.

85. I propose, therefore, to take the silting channel from the Chinna Moollyar just below its junction with the Sairveyellar. The level of the bed of the channel here will be 140 feet above datum; its length to the site of the dam will be 23,000 feet, so that allowing a fall of 1 in 1,000, it will reach the dam at the level of 117 feet.

86. The drainage area of the Chinna Moollyar, at the point where the channel leaves it, is about 12 square miles, or one-twentieth that of the Perryaur at the site of the dam.

87. Taking the discharges of the two streams, as holding the same proportion to one another as their drainage areas, and neglecting as "fresh" in the larger stream all discharges above 500 cubic feet a second, I find from our daily records of discharge during the last season that we can confidently calculate on a supply from the Chinna Moollyar of from 22 to 24 cubic feet per second from July to December, of 18 cubic feet in January, and 6 cubic feet* in February.

* This is less than one-twentieth the discharge of the Perryaur, but the Chinna Moollyar is more dependent on local rain, and the discharge therefore diminishes more rapidly in dry weather. The stream was gauged during the latter part of last season, but the observations were too few to be of much value.

88. These quantities are those which will be actually brought down by the channels; but as the work will only be carried on during nine hours out of the twenty-four, the water brought down during the other fifteen may be stored in small reservoirs, constructed in favourable positions, of which many may be found near the site of the dam, so that the actual amount of water available for silting will be $2\frac{2}{3}$ times that stated in the last paragraph. The cost of these reservoirs will be very slight; provision has been made for them in the estimate,† and one or two favourable sites indicated on the Plan (No. 4), but there are many others equally good.

† No I.

89. The amount of earth deposited by a given quantity of water depends on the nature of the soil and the gradient of the branch silting channels. As an average, it is believed that about 40 cubic yards of earth per hour, or 360 cubic yards in a day of nine hours, will be deposited by one cubic foot of water per second.

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90. The *maximum* quantity which I propose to use directly for silting from one bank is seven cubic feet and a half a second,* and the surplus will be made use of in order to obtain a supply of water for transporting the earth which lies at a higher level than can be commanded by the main channels.

* 20 cubic feet during working hours, which will suffice for the execution of 7,200 cubic yards of earth in a day.

91. This course was first suggested by Lieutenant Greer, who proposed the use of hydraulic rams for the purpose of raising the water required; but after consultation with Messrs. Gwynne and Co., the well-known Hydraulic Engineers, I have come to the conclusion that the best way will be to use force pumps, driven by turbines, the latter being worked by the water brought from the Chinna Moollyar.

92. The machinery provided in the estimate† will be sufficient to raise about 6 cubic feet per second to an *average* height of 90 feet above the level of the main channel, by an expenditure of double that amount in working the turbines. This will give during working hours an available daily supply of $6 \times \frac{24}{9} = 16$ cubic feet per second, if required.

† No. IX. (*f.*)

93. In order to turn the stream of the Chinna Moollyar into the silting channel, I propose to erect a concrete dam of the dimensions shown in Plan No. 3. A dam of this nature appears preferable to one of earth, as although the latter would cost less in construction, it would involve a heavy expense in cutting an escape channel through the bank at the side of the dam, in order to prevent the latter from being swept away by floods two or three times in the course of each season.

94. The head of the channel will be protected by a wing-wall, and the water conveyed to it by a 21-inch pipe, the mouth of which can be partially or entirely closed by a sluice valve if it be required to shut off the water from the channel. The level of the pipe has been fixed so that no water shall pass over the dam until the discharge of the river exceeds 25 cubic feet per minute. The maximum amount which the channel will carry (the depth being 2 feet) is 32·3 cubic feet per second.

95. The channel is shown in section on Plan No. 3. The earth excavated in its formation will of course be thrown on the outside, so as to form an embankment to the outer edge of the channel. This is not shown in the section.

96. In order to avoid the length of line, and consequent extra fall necessary for carrying the channel round the numerous ravines with which the ground is intersected, I propose to carry it across these by means of wooden troughs, supported on bamboo trestles. These can be easily and cheaply made, as materials will be found on the spot.

97. On the left bank of the Perryaur examination of the ground has shown that the only stream which can be made use of for silting is the Arinashi,‡ which joins the Perryaur rather more than four miles above the site of the dam. We have no means of judging accurately what the discharge of this stream may be, as its drainage basin is altogether unsurveyed, and it is too rapid to gauge with such means as were at our disposal last year except in very dry weather. It is, however,

‡ Plan No. 2.

not much smaller than that of the Chinna Moollyar, and would be sufficient for our purpose were it only one-half the amount, the supply of earth on the left bank being less than that on the right, and a much larger proportion of it being below the main silting channel.

98. The same principles have been followed in dealing with this stream as with the Chinna Moollyar. The dimensions of the dam and channel are shown on Plan No. 3. The maximum discharge of the channel will be $24\frac{1}{2}$ cubic feet per second, and no water will pass over the dam until the discharge of the river reaches 22 cubic feet per second.

99. The cost of the silting apparatus has been shown separately in Estimate No. I., in order to enable it to be compared with the amount saved by the use of the silting process. It will be seen that this estimate amounts to Rupees 94,000, and that the use of the silting process enables us to execute for Rupees 1,67,000 an amount of earthwork (2,000,000 cubic yards) which we could certainly not execute by manual labour for less than 800,000. The cost of the apparatus for raising the water is Rupees 50,000, and this enables us to execute by silting for Rupees 1,03,000 (1,232,000 cubic yards) earthwork which are not commanded by the main channels, and which would cost by manual labour Rupees 4,60,000 at least.

100. The completion of the culvert, silting channels, and dams, with all preparations that may be necessary for the commencement of the earthwork, is calculated to occupy the first season, during which also the blasting for the escape will be steadily carried on.

101. At the commencement of the second season a rough-stone dam, 15 feet high, will be thrown across the river from each end of the culvert, and the interstices between the stones silted in so as to make the dams as nearly water-tight as possible. The ordinary stream of the river will then pass through the culvert, and still-water being thus obtained in the rest of the river bed the earthwork from the left bank will be carried out to within 120 feet of the outer edge of the culvert, and to the full thickness of the dam at its base. Above this it will have a front slope of 2 to 1, a rear slope of 3 to 1, and an end slope (towards the river) of 1 to 1.

102. The earthwork on the right bank above the culvert will be carried on in the same way throughout the season.

103. The side slopes of the central opening will be revetted with stone to 55 feet above datum at the upper end, and 45 at the lower, to protect the earthwork from erosion during floods and freshes, which will of course pass over the rough-stone dams. The rear slope of the dam will also be revetted up to 40 feet above datum.

104. It is calculated that during the second season the earthwork may be carried to 110 feet above datum on the left bank, and to 120 feet on the right bank.*

* Plan No. 5.

105. During the third season the two flank portions of the dam will be completed to their full height.

106. During the first part of the fourth season the central opening will be closed up to a height of 120 feet.† The dam thus formed to have a top width of 20 feet, a front slope of 2 to 1, and a rear slope of 3 to 1. It is probable

† Plan No. 6.

that the rough-stone dams across the central opening will have been a good deal damaged by the floods of the two previous seasons, but enough of them will remain to turn the stream through the culvert during nine days out of ten, and thus allow the lower part of the earthwork to be carried out without interruption.

107. It is during this period that there will be the greatest risk of injury to the earthwork by freshes, as a heavy flood occurring during the time occupied in constructing the lower part of the central dam would sweep over and carry away more or less of the work. It is however improbable, though not impossible, that a flood of any great extent should occur in August or September, and the risk is really not very great. At any rate it cannot be avoided, whatever its extent may be.

108. During the latter part of the fourth season the central opening will be filled in to its full width up 120 feet above datum.

109. It may possibly be considered better to increase the height of the dam across the central opening during this period, instead of merely increasing its thickness at the base. In this case it might be raised to 180 feet, keeping the top width at 20 feet. This would of course have the effect of rendering the work still more secure against floods during the next south-west monsoon, but as the height of 150 feet is amply sufficient for this purpose it does not seem of much consequence which course is adopted.

110. During the first part of the fifth season the central opening will be completely closed to its full height and width.*

* Plan No. 7.

111. There will then only remain the opening in rear of the culvert, which will be filled in as soon as the fall of the river at the close of the north-east monsoon enables the culvert to be closed without difficulty.

112. This will probably be early in December; stout wooden frames, previously prepared, will be inserted in grooves left for that purpose in the piers of the culvert, the spaces between these frames will be filled up with concrete, and the culvert in rear of them will also be filled up with the same material to a total length of 100 feet.

113. The remainder of the culvert will then be filled in with earth, and the opening in its rear filled up. There will be no difficulty in carrying out this by the end of the working season, and the dam will then be complete. Its front slope will be revetted with stone from 151 feet above datum (6 feet below the sill of the cutting) to 196 feet (6 feet above the highest water level of the lake).

114. The execution of the escape and cutting will proceed at the same time with that of the dam. The former does not seem to call for any remark; a few words are required concerning the sluice dam for regulating the discharge through the latter.

115. It has been stated† that the maximum amount of water to be thrown into the Sooroollyar should not greatly exceed one million cubic yards an hour. In order thus to limit the discharge, and at the same time to enable the cutting to pass the ordinary supply of the river with only a moderate depth on its sill, it is proposed to close the upper part of the cutting by a dam, leaving an opening below for the passage of water.

† Paragraph 27.

116. Calculation shows the best arrangement* for this purpose to be three arches with a span of 10 feet, and a height up to the springing line of 6 feet 9 inches above the sill of the cutting. Two piers, 5 feet thick, will make a total width of 40 feet, and the cutting will therefore be enlarged from 30 feet (its ordinary width) to 40 feet, at the site of the sluice dam.

* Plan No. 9.

117. This sluice will pass 160,000 cubic yards an hour, with a depth on the sill of the cutting of a little over 6 feet, while the greatest discharge (with the lake level at 190) will be 1,103,000 cubic yards an hour. Sluice gates may, if necessary, be added still further to regulate the discharge, but they do not appear to be necessary.

118. It is proposed to build the upper part of this dam of concrete; the arches and their piers I propose to build of cut-stone, as it is possible that, in the course of years, concrete might be injured by the constant passage of water through the arches. A masonry dam will be cheaper than one of earth, as the extra length of culverts required for the latter would more than compensate for the saving which would be effected in the upper portion of so small a dam as this. The level of the top of this dam, has been purposely made 4 feet lower than that of the main dam on the Perryaur.

119. The other branches of the general estimate may be very briefly dismissed.

120. The estimate of the road† speaks for itself; the line has been carefully surveyed, and the quantities in the estimate are based upon actual measurements taken along the whole line. The ruling gradient of the ghaut is 1 in 15. At the end of last season, a 6-foot path had been cut from the foot of the ghaut to the saddle‡ to the east of the dam site, and a short length widened out to 18 feet.

† No. V.

‡ B. on Plan No. I.

121. For the Officer's and Overseer's quarters,‖ offices, store-sheds, workshops, etc., I propose to erect wooden huts with thatched roofs; for the workmen and maistries, thatched buildings such as have hitherto been used for every one, officers included, appear suitable, the materials for their construction being found on the spot in unlimited quantities; the cost of providing these is included in the rate for labour.§

‖ Estimate No. VI.

§ Table of Data No. I.

122. On Plans No. 1 and No. 4 are indicated, in a general way, what appear the best positions for the various buildings; but the individual arrangement of these is a matter of executive detail, to which it would be out of place to allude in a report like the present. For the same reason I have not touched on such details, as the mode of collecting, organizing, and paying workmen, although I have naturally given a certain amount of consideration to them.

123. The establishment provided¶ for is:—

¶ Estimate No. VII.

4 Overseers, at Rupees 100 each per month.
2 Medical Subordinates, at Rupees 100 each.

4 Writers and Accountants, at (in all) Rupees 190.
28 Lascars, at Rupees 10 each.

Except during the first and last seasons, when two Overseers and one Medical Subordinate only will be required.

The cost of petty supervision is included in the rate of labour.

124. Provision has been made of Rupees 30,000* on account of preliminary surveys and other similar expenses; nearly this sum had been expended on the project up to the end of February last, and by this time the expenditure will probably be more, but the greater part of it has been spent on the construction of the road, and will come out of the sum (Rupees 1,60,000) provided for that portion of the work. It is believed that the sum named will amply cover the cost of the surveys, etc.

* Estimate No. VIII.

125. A separate estimate† is given of the amount and cost of machinery, tools and plant required, which has afterwards been distributed amongst the principal heads into which the general estimate is divided. No deduction has been made on account of value after use, although some of the machinery, especially that for raising water, making concrete, and stone-breaking, will probably be found very useful in other works.

† No. IX.

126. The rates allowed for labour are those which experience has shown to be necessary. They are much higher than are paid under ordinary circumstances, owing to the extreme unhealthiness of the climate and the necessity for bringing all the food for the workpeople from a distance of 20 miles.

127. The number of workmen required to complete the work in the time named will be nearly as follows:—

Coolies from	700 to 1,100
Miners	200
Carpenters	12
Smiths	20

128. The amount of work expected to be done to the dam in each season is based upon a detailed calculation of the number of days required for executing each 10 feet of height in each of the five parts into which the dam is divided, taking into consideration the supply of water for silting and the proportions to be executed by silting and by manual labour, and the rate of progress thus found is that which we may confidently reckon on being able to attain. It is not at all improbable that we may be able to work faster than this, if we can obtain sufficient labour,‡ or if the day's work of a cooly turns out (though this I do not expect) to be greater than I have allowed.

‡ My calculations have been limited by a *maximum* of 1,100 coolies, *i.e.*, 1,000 available for work, and I am convinced that my estimate of the supply of water for silting is a very moderate one.

129. I cannot conclude this report without acknowledging the assistance rendered by Lieutenants Coaker and Greer, in making the surveys and other preliminary investigations connected with the project. Lieutenant Coaker worked with me from the time when I was first appointed to this duty, and in spite of his

constant bad health, and the extremely arduous nature of the work, his energy never flagged until we were both compelled to quit Madura. Lieutenant Greer was not so long employed on the project, but while he was with me his intelligence* and interest in the work rendered his services extremely valuable. Whoever is eventually employed in superintending the execution of this project could not have better assistance than would be furnished by these two Officers.

* I have already mentioned that it was Lieutenant Greer who originally suggested the use of the surplus water of the Chinna Moollyar for obtaining a smaller supply at a higher level, which enables us to do nearly three times as much work by silting as we could do without raising the water in this manner.

130. I believe that the information contained in this report, and the papers forwarded with it, will enable Government to come to a definite conclusion regarding the execution of this project. That the work will be a difficult one, requiring constant care and untiring energy on the part of every one concerned, there can be no doubt; in my own mind there is as little of its entire feasibility.

(Signed) J. PENNYCUICK, Captain, R.E.,
Executive Engineer.

HAMPTON COURT,
14th November 1870.

TABLE I.—*Table of Rain-fall and discharge of River as observed during 1869-70.*

Months.	Rain-fall. At upper camp.	Rain-fall. At lower camp.	Discharge of River. Total discharge during month.	Depth run off from drainage area of 250 sqr. miles.	Maximum during month.	Minimum during month.	Average. Per day.	Average. Per hour.	Average. Per minute.	Average. Per second.
	Inches.		1,000 Cub. yds.	Inches.	Cubic feet. Per second.		1,000 Cub. yds.		Cubic feet.	
July 1869.	6·25	8·00	89,672	4·17	2,350	435	2,893	120·5	54,244	904
August ,,	8·48	9·96	103,259	4·75	6,322	483	3,331	138·8	62,456	1,041
Sept. ,,	5·47	6·24	68,209	3·17	3,871	354	2,274	94·7	42,637	711
Oct. ,,	10·39	8·57	69,912	3·25	5,780	314	2,255	94·2	42,281	705
Nov. ,,	13·19	14·11	*496,396	23·08	127,129	742	16,547	517·1	310,247	5,171
Dec. ,,	1·56	2·47	100,160	4·66	3,901	454	3,231	134·6	60,581	1,010
Jan. 1870.	0·83	0·85	56,184	2·61	2,348	339	1,812	75·5	33,975	566
Feb. ,,	0·09	0·05	25,566	1·19	609	210	913	38·0	17,118	285

* Of this there passed in		During 7th and 8th. (Thousand cubic yards.)	During 17th to 20th. (Thousand cubic yards.)
Of this there passed in	3 hours	4,000	 46,404
Do.	in 6 ,, ...	7,878	 82,961
Do.	in 12 ,, ...	13,532	 136,966
Do.	in 24 ,, ...	21,672	 209,623
Do.	in 48 ,, ...	38,445	 280,499
Do.	in 96 ,, ...	......	 314,073

222 millions (nearly) would have been discharged over the escape.

TABLE II.—*Discharge of the Perryaur at site of Dam for various surface levels.*

Level above datum.	Discharge. Cubic feet per minute.	Discharge. Cubic feet per second.	Discharge. 1,000 cubic yards per hour.	Level above datum.	Discharge. Cubic feet per minute.	Discharge. Cubic feet per second.	Discharge. 1,000 cubic yards per hour.
Feet.				Feet.			
0	21,666	361	48	15	1,720,406	28,673	3,823
1	44,087	735	98	16	1,949,822	32,947	4,333
2	79,534	1,326	177	17	2,189,703	36,495	4,866
3	122,913	2,049	273	18	2,439,806	40,663	5,422
4	182,785	3,046	406	19	2,706,960	45,116	6,015
5	255,187	4,253	567	20	2,995,768	49,929	6,657
6	336,240	5,604	747	21	3,330,166	55,503	7,400
7	428,166	7,136	951	22	3,721,587	62,026	8,270
8	531,089	8,851	1,180	23	4,158,105	69,302	9,240
9	648,369	10,806	1,441	24	4,634,130	77,236	10,298
10	778,386	12,973	1,730	25	5,155,554	85,926	11,457
11	926,767	15,446	2,059	26	5,717,301	95,288	12,705
12	1,095,608	18,267	2,435	27	6,335,480	105,591	14,079
13	1,285,048	21,417	2,856	28	6,976,677	116,278	15,504
14	1,494,633	24,911	3,321	29	7,641,848	127,364	16,982

NOTE.—The datum level of this and other tables is the top of a rock in the bed of the river at the upper or No. 1 site, and very fairly represents the ordinary low-water level of the stream at that point.

The velocities and discharges corresponding to various surface levels from 0 to 37 feet at No. 1 site were ascertained by numerous observations during 1869-70, and the surface fall between sites No. 1 and No. 2 for several levels was also observed; the above table of discharges at No. 2 site has been calculated from the data thus obtained.

The amount of drainage received by the Perryaur between the two sites is very trifling, and has been neglected in this calculation.

TABLE III.—*Table of area of Lake surface and content of Lake at various levels.*

Level above datum.	Area of lake surface.	Content of lake.	Total content.	Level above datum.	Area of lake surface.	Content of lake.	Total content.	Level above datum.	Area of lake surface.	Content of lake.	Total content.
Feet.	1,000 sqr. yds.	1,000 cubic yards.		Feet.	1,000 sqr. yds.	1,000 cubic yards.		Feet.	1,000 sqr. yds.	1,000 cubic yards.	
0	125·0			105	3,066·5	4,888·9	44,522·1	170	8,107·5	2,685·6	159,673·0
5	142·5	222·9	222·9	110	3,346·0	5,343·7	49,865·8	171	8,209·8	2,719·5	162,392·5
10	195·0	281·2	504·1	115	3,638·5	5,820·4	55,686·2	172	8,312·7	2,753·8	165,146·6
15	282·5	397·9	902·0	120	3,944·0	6,318·8	62,005·0	173	8,416·2	2,788·1	167,934·4
20	405·0	572·9	1,474·9	125	4,262·5	6,838·7	68,843·7	174	8,520·3	2,822·8	170,757·2
25	562·5	806·3	2,281·2	130	4,619·5	7,401·7	76,245·4	175	8,625·0	2,857·5	173,614·7
30	645·0	1,006·2	3,287·4	135	4,990·5	8,008·3	84,253·7	176	8,730·3	2,892·6	176,507·3
35	742·5	1,156·3	4,443·7	140	5,375·5	8,638·3	92,892·0	177	8,836·2	2,927·7	179,435·0
40	855·0	1,331·2	5,774·9	145	5,774·5	9,291·7	102,183·7	178	8,942·7	2,963·2	182,398·2
45	982·5	1,531·3	7,306·2	150	6,187·5	9,968·3	112,852·0	179	9,049·8	2,998·7	185,396·9
50	1,125·0	1,756·2	9,062·4	155	6,645·0	10,693·7	122,845·7	180	9,157·5	3,034·6	188,431·5
55	1,230·0	1,962·5	11,024·9	160	7,117·5	11,468·8	134,314·5	181	9,265·8	3,070·5	191,502·0
60	1,345·0	2,145·8	13,170·7	161	7,213·8	2,388·5	136,703·0	182	9,374·7	3,106·8	194,608·8
65	1,470·0	2,345·8	15,516·5	162	7,310·7	2,420·8	139,123·8	183	9,484·2	3,143·1	197,751·9
70	1,605·0	2,562·5	18,079·0	163	7,408·2	2,453·1	141,576·9	184	9,594·3	3,179·8	200,931·7
75	1,750·0	2,795·8	20,874·8	164	7,506·3	2,485·8	144,062·7	185	9,705·0	3,216·5	204,148·3
80	1,936·0	3,071·7	23,946·5	165	7,605·0	2,518·5	146,581·2	186	9,816·8	3,253·6	207,401·8
85	2,134·0	3,391·7	27,338·2	166	7,704·3	2,551·6	149,132·8	187	9,928·2	3,290·7	210,692·5
90	2,344·0	3,731·6	31,069·8	167	7,804·2	2,584·7	151,717·5	188	10,040·7	3,328·2	214,020·7
95	2,566·0	4,091·7	35,161·5	168	7,904·7	2,618·2	154,335·7	189	10,153·8	3,365·7	217,386·4
100	2,800·0	4,471·7	39,633·2	169	8,005·8	2,651·7	156,987·4	190	10,267·5	3,403·5	220,789·9
		4,888·9				2,685·6					

TABLE IV.—*Table showing rise of Lake surface during an ordinary big fresh. Sill of cutting at 157.*

Level of lake surface.	Content of lake.	Discharge of river	Discharge of cutting.	Stored in lake.	Time.	Total stored above 164 feet level.	Level.	—
Feet.	1,000 C. yards.	1,000 cubic yards per hour.			Hour.	1,000 C. yards.	Feet.	
164 to 165·0	2,518·5	333 / 500	218	115 / 282	12·0 / 4·04	1,380·0	164·55	4 Millions cubic yards in 12 hours.
165 to 166·0	2,551·6	500 / 750	263	237 / 487	7·96 / 1·36	4,415·0	165·74	6 do. in do.
166 to 167·0	2,584·7	...	310	440	5·87			
167 to 168·0	2,618·2	750 / 1,000	359	391 / 641	4·77 / 1·19	9,519·9	167·71	9 do. in do.
168 to 169·0	2,651·7	...	410	590	4·49			
169 to 170·0	2,685·6	...	462	538	5·0			
170 to 171·0	2,719·5	1,000 / 1,333	515	485 / 818	1·32 / 2·50	16,250·5	170·24	12 do. in do.
171 to 172·0	2,753·8	1,333 / 1,000	565	768 / 435	3·50 / 0·16	21,017·8	171·98	8 do. in 6 do.
172 to 173·0	2,788·1	...	612	388	7·19			
173 to 173·58	1,636·8	1,000 / 437½	648	352	4·65	25,508·5	173·58	12 do. in 12 do.
				Lake commences to fall			... ...	10½ do. in 24 do.

NOTE.—The discharges given in the above table are those assumed by Captain Ryves for "an ordinary big fresh," which was to be exceeded before any water should pass over the escape.

No flood of this extent occurred during 1869-70, except the great one on the 17th and 18th November 1869.

The largest fresh next to this occurred on the 7th and 8th November, and would have raised the level of the lake surface to 171·15.

The level of 174 for the escape, as found from the above table, appears therefore suitable.

TABLE V.—*Table showing rise and fall of Lake surface during a great flood. Sill of cutting at 157. Crest of escape at 174.*

Level of lake surface.	Content of lake.	Discharge of river.	Discharge of cutting.	Discharge over escape.	Stored in lake.	Time.	Total stored above 164 feet level.	Level.	—
Feet.	1,000 C. yds.	1,000 cubic yards per hour.				Hour.	1,000 cubic yards.	Feet.	
167 to 168	2,618·2	4,000	359	......	3,641	0·72			
168 to 169	2,651·7	......	410	......	3,590	0·74			
169 to 170	2,685·6	......	462	......	3,538	0·76			
170 to 171	2,719·5	......	515	......	3,485	0·78			
171 to 172	2,753·8	......	565	......	3,435	0·80			
172 to 173	2,788·1	......	612	......	3,388	0·82			
173 to 174	2,822·8	......	655	......	3,345	0·84			
174 to 175	2,857·5	4,000 / 6,671	693	95	3,212 / 5,803	0·54 / 0·19	28,429·0	174·61	24 millions cubic yds. in 6 hours.
175 to 176	2,892·6	......	727	364	5,580	0·52			
176 to 177	2,927·7	......	757	763	5,151	0·57			
177 to 178	2,963·2	......	786	1,255	4,630	0·64			
178 to 179	2,998·7	......	813	1,824	4,034	0·74			
179 to 180	3,034·6	6,671 / 8,812	840	2,461	3,370 / 5,511	0·34 / 0·34	42,480·0	179·38	20,014,000 do. in 3 hours.

TABLE V.—(Concluded.)

Level of lake surface.	Content of lake.	Discharge of river.	Discharge of cutting.	Discharge over escape.	Stored in lake.	Time.	Total stored above 164 feet level.	Level.	——
Feet.	1,000 C. yds.	1,000 cubic yards per hour.				Hour.	1,000 cubic yards.	Feet.	
180·0 to 181·0	3,070·5	......	866	3,159	4,787	0·64			
181·0 to 182·0	3,106·8	......	892	3,913	4,007	0·78			Cubic yds.
182·0 to 183·0	3,143·1	......	918	4,721	3,173	0·99			
183·0 to 183·10	323·0	......	943	5,577	1,292	0·25	54,012·2	183·10	26,435,000 in 3 hours.
					Drawn from lake.				
183·10 to 183·0	323·0	5,503	943	5,577	1,017	0·32			
183·0 to 182·0	3,143·1	5,503 3,567	918	4,721	136 2,072	2·68 1·35	53,332·8	182·89	16,510,000 in do.
182·0 to 181·34	2,042·7	......	892	3,913	1,238	1·65	48,502·9	181·34	10,700,000 in do.
					Stored				
181·34 to 182·0	2,042·7	10,668	892	3,913	5,863	0·35			
182·0 to 183·0	3,143·1	......	918	4,721	5,029	0·62			
183·0 to 184·0	3,179·8	......	943	5,577	4,148	0·77			
184·0 to 185·0	3,216·5	......	968	6,477	3,223	1·0			
185·0 to 186·0	3,253·6	10,668 15,468	993	7,423	2,252 7,052	0·26 0·38	60,674·0	185·15	32,005,000 in do.
186·0 to 187·0	3,290·7	......	1,018	8,411	6,039	0·54			
187·0 to 188·0	3,328·2	......	1,042	9,449	4,977	0·67			
188·0 to 189·0	3,365·7	......	1,067	10,523	3,878	0·87			
189·0 to 189·48	1,643·4	......	1,085	11,340	3,043	0·54	74,966·9	189·48	46,404,000 in do.
					Drawn from lake.				
189·48 to 189·0	1,643·4	12,186 7,333	1,085	11,340	239 5,092	3·0 0·18	74,259·9	189·27	36,557,000 in do.
189·0 to 188·0	3,365·7	......	1,067	10,523	4,257	0·79			
188·0 to 187·0	3,328·2	......	1,042	9,449	3,158	1·05			
187·0 to 186·0	3,290·7	7,333 5,614	1,018	8,411	2,096 3,815	0·98 0·33	64,575·7	186·38	22,000,000 in do.
186·0 to 185·0	3,253·6	......	993	7,423	2,802	1·16			
185·0 to 184·0	3,216·5	5,614 3,575	968	6,477	1,831 3,870	1·51 0·11	57,320·7	184·15	16,841,000 in do.
184·0 to 183·0	3,179·8	......	943	5,577	2,945	1·08			
183·0 to 182·0	3,143·1	......	918	4,721	2,064	1·52			
182·0 to 181·0	3,106·8	3,575 1,814	892	3,913	1,230 2,991	0·29 0·92	50,199·4	181·89	10,726,000 in do.
181·0 to 180·0	3,070·5	......	866	3,159	2,211	1·39			
180·0 to 179·0	3,034·6	......	840	2,461	1,487	2·04			
179·0 to 178·0	2,998·7	1,814 1,271	813	1,824	823 1,366	1.65 1·20	39,976·3	178·55	10,887,000 in 6 hours.
178·0 to 177·0	2,963·2	......	786	1,255	740	4·0			
177·0 to 176·0	2,927·7	1,271 1,077 1,030	757	763	249 443 490	0·80 6·0 0·14	35,173·1 32,515·1	176·94 176·02	7,624,000 6,461,000
176·0 to 175·0	2,892·6	1,030 836 665	727	364	61 255 426	5.86 6·0 2·36	32,087·1 30,557·1	175·88 175·35	6,180,000 5,017,000 In 6 hours,
175·0 to 174·0	2,857·5	665 542	693	95	123 246	3·61 9·80	29,104·3 26,694·5	174·84 174·0	3,987,000 6,505,000 in 12 hours.

Total amount discharged over escape—221,873,000, cubic yards.

TABLE VI.—*Table showing rise of Lake surface from a great flood occurring during the construction of the latter part of the Dam.*

Level of lake surface.	Content of lake.	Discharge of river.	Discharge of culvert.	Stored in lake.	Time.	Level.	—
Feet.	1,000 C. yds.	1,000 cubic yards per hour.			Hour.	Feet.	
5 to 10·0	281·2	4,000	633	3,367	0·08		
10 to 15·0	397·9	......	858	3,142	0·13		
15 to 20·0	572·9	......	1,071	2,929	0·20		
20 to 25·0	806·3	......	1,264	2,736	0·30		
25 to 30·0	1,006·2	......	1,688	2,312	0·44		
30 to 35·0	1,156·3	......	2,353	1,647	0·70		
35 to 40·0	1,331·2	......	2,727	1,273	1·05		
40 to 45·0	1,531·3	......	3,017	983	1·56		
45 to 50·0	1,756·2	4,000 6,671	3,278	722 3,393	1·54 0·19	48·17	24 millions cubic yards in 6 hours.
50 to 55·0	1,962·5	......	3,521	3,150	0·62		
55 to 60·0	2,145·8	......	3,753	2,918	0·74		
60 to 65·0	2,345·8	......	3,968	2,703	0·87		
65 to 70·0	2,562·8	6,671 8,812	4,172	2,499 4,640	0·58 0·24	67·83	20,014,000 cubic yards in 3 hours.
70 to 75·0	2,795·8	......	4,366	4,446	0·63		
75 to 80·0	3,071·7	......	4,551	4,261	0·72		
80 to 85·0	3,391·7	......	4,730	4,082	0·83		
85 to 90·0	3,731·6	8,812 5,510	4,904	3,908 606	0·58 2·55	87·93	26,435,000 do. in do.
90 to 90·28	229·5	......	5,000	510	0·45	90·28	16,510,000 do. in do.
				Drawn from lake.			
90·28 to 90·0	229·5	3,567	5,000	1,433	0·16		
90·0 to 85·0	3,731·6	......	4,904	1,337	2·79		
85·0 to 84·92	62·6	......	4,810	1,243	0·05	84·92	10,700,000 do. in do.
				Stored in lake.			
84·92 to 90·0	3,794·2	10,668	4,902	5,764	0·65		
90·0 to 95·0	4,091·7	......	5,071	5,597	0·73		
95·0 to 100·0	4,471·9	10,668	5,231	5,437	0·82		
100·0 to 105·0	4,888·9	10,668 15,468	5,385	5,283 10,083	0·80 0·07	104·32	32,005,000 do. in do.
105·0 to 110·0	5,343·7	......	5,535	9,933	0·54		
110·0 to 115·0	5,820·4	......	5,686	9,782	0·60		
115·0 to 120·0	6,318·8	......	5,972	9,496	0·67		
120·0 to 125·0	6,838·7	.....	6,109	9,359	0·73		
125·0 to 130·0	7,401·7	15,468 12,186	6,243	9,225 5,943	0·39 0·64	127·43	46,404,000 do. in do.
130·0 to 135·0	8,008·3	......	6,374	5,812	1·38		
135·0 to 139·66	8,055·4	12,186 7,333 5,614	6,504	5,682 829 Commences to fall.	0·98 3·0	138·22 139·66	36,557,000 do. in do. 22 millions do. in do. 16,841,000 do. in do.

NOTE.—The discharges given in the above Tables (V. and VI.,) are those of a flood which actually occurred on the 17th—20th November 1869. For short periods they are somewhat greater than those of the flood assumed by Captain Ryves as the greatest possible.

There is good evidence that this flood was of very unusual, if not of altogether unprecedented, magnitude; it has therefore been considered advisable to calculate the level to which the lake would rise from it, rather than from an imaginary series of discharges.

HAMPTON COURT,
14th November 1870.

(Signed) J. PENNYCUICK, Captain, R.E.,
Executive Engineer.

QUANT

Table I.—*Earth-*

Level above datum.	Right Bank.				Left Bank.				150 Feet Dam in	
	Mean length.	Mean breadth.	Area of horizontal section.	Content.	Mean length.	Mean breadth.	Area of horizontal section.	Content.	Mean length.	Mean breadth.
Feet.	Feet.	Feet.	Sq. Ft.	Cub. yds.	Feet.	Feet.	Sq. Ft.	Cub. yds.	Feet.	Feet.
				300				5,789		
0	......	......	5,000		58 × − 143 ×	1,061 66	= 52,100		120 × − 240 ×	770 66 =
				2,370				23,313		
10	... ..	......	7,800		77 × − 156 ×	1,011 26	= 73,791		130 × − 260 ×	720 26 =
				3,815				30,571		
20	......	......	12,800		95 ×	961	= 91,295		140 ×	670 =
				7,107				34,283		
30	48 × − 65 ×	912 280	= 25,576		103 ×	911	= 93,833		155 ×	620 =
				14,792				34,895		
40	83 × − 65 ×	861 264	= 54,303		110 ×	860	= 94,600		175 ×	570 =
				24,943				34,919		
50	119 × − 65 ×	811 248	= 80,389		116 ×	810	= 93,960		195 ×	520 =
				32,502				36,234		
60	145 × − 65 ×	760 232	= 95,120		134 ×	759	=101,706		215 ×	470 =
				37,761				38,923		
70	173 × − 65 ×	710 216	=108,790		153 ×	709	=108,477		235 ×	420 =
				43,489				40,316		
80	211 × − 65 ×	659 200	=126,049		166 ×	658	=109,228		255 ×	370 =
				50,289				40,044		
90	259 × − 65 ×	608 184	=145,512		176 ×	608	=107,008		275 ×	320 =
				56,694				38,899		
100	308 × − 65 ×	557 168	=160,636		185 ×	557	=103,045		295 ×	270 =
				58,995				37,917		
110	331 × − 65 ×	507 152	=157,937		201 ×	506	=101,706		315 ×	220 =
				57,673				36,990		
120	356 × − 65 ×	456 136	=153,496		215 ×	456	= 98,040		335 ×	170 =
				55,250				35,481		
130	376 × − 65 ×	406 120	=144,856		231 ×	405	= 93,555		355 ×	120 =
				51,146				33,694		
140	389 × − 65 ×	355 104	=131,335		249 ×	355	= 88,395		375 ×	70 =
				46,024				31,288		
150	403 × − 65 ×	305 88	=117,195		265 ×	304	= 80,560		395 ×	20 =
				40,451				28,277		
160	417 × − 65 ×	254 72	=101,238		284 ×	254	= 72,136			
				34,356				24,711		
170	431 × − 65 ×	204 56	= 84,284		302 ×	203	= 61,306			
				28,217				20,505		
180	462 × − 65 ×	153 40	= 68,086		323 ×	153	= 49,419			
				22,009				15,668		
190	508 × − 65 ×	103 24	= 50,764		345 ×	102	= 35,190			
				14,639				9,992		
200	554 × − 65 ×	52 8	= 28,288		368 ×	51	= 18,768			
				4,039				2,657		
205	568 ×	27	= 15,336		382 ×	26	= 9,932			
	Total up to 120 feet ...			390,730	Total up to 110 feet ...			396,103		
	,, above ,, ,, ...			296,131	,, above ,, ,, ...			239,263		
				686,861				635,366		

ITIES.

work in Dam.

CENTRAL OPENING.		REMAINDER OF CENTRAL OPENING.				OPENING OVER END OF CULVERT.				Total Content.
Area of horizontal section.	Content.	Mean length.	Mean breadth.	Area of horizontal section.	Content.	Mean length	Mean breadth.	Area of horizontal section.	Content.	
Sq. Ft.	Cub. yds.	Feet.	Feet.	Sq. Ft.	Cub. yds.	Feet.	Feet.	Sq. Ft.	Cub. yds.	Cub. yds.
	8,396				3,920				811	19,216
75,560		120 ×	294	= 35,280		40 × + 27 ×	365 552	= 29,504		
	30,074				13,067				11,946	80,770
86,840		120 ×	294	= 35,280		60 × + 27 ×	335 552	= 35,004		
	33,452				13,067				13,761	94,666
93,800		120 ×	294	= 35,280		80 × + 27 ×	305 552	= 39,304		
	35,167				13,157				9,654	99,368
96,100		do. + 35 ×	14	= 35,770		100 ×	280	= 28,000		
	36,269				13,463				11,052	110,471
99,750		do. + 55 ×	30	= 36,930		120 ×	264	= 31,680		
	37,250				14,011				12,296	123,419
101,400		do. + 75 ×	46	= 38,730		140 ×	248	= 34,720		
	37,491				14,796				13,304	134,327
101,050		do. + 95 ×	62	= 41,170		160 ×	232	= 37,120		
	36,991				15,819				14,074	143,568
98,700		do. + 115 ×	78	= 44,250		180 ×	216	= 38,880		
	35,750				17,078				14,607	151,240
94,350		do. + 135 ×	94	= 47,970		200 ×	200	= 40,000		
	33,769				18,574				14,904	157,580
88,000		do. + 155 ×	110	= 52,330		220 ×	184	= 40,480		
	31,046				20,307				14,963	161,909
79,650		do. + 175 ×	126	= 57,330		240 ×	168	= 40,320		
	27,583				22,278				14,785	161,558
69,300		do. + 195 ×	142	= 62,970		260 ×	152	= 39,520		
	23,380				24,485				14,370	156,898
56,950		do. + 215 ×	158	= 69,250		280 ×	136	= 38,080		
	18,435				26,930				13,719	149,815
42,600		do. + 235 ×	174	= 76,170		300 ×	120	= 36,000		
	12,750				29,611				12,830	140,031
26,250		do. + 255 ×	190	= 83,730		320 ×	104	= 33,280		
	6,324				32,530				11,704	127,870
7,900		do. + 275 ×	206	= 91,930		340 ×	88	= 29,920		
					33,226				10,341	112,295
		415 × — 295 ×	262 72	= 87,490		360 ×	72	= 25,920		
					30,013				8,741	97,821
		435 × — 315 ×	212 56	= 74,580		380 ×	56	= 21,280		
					24,980				6,904	80,606
		455 × — 335 ×	162 40	= 60,310		400 ×	40	= 16,000		
					19,355				4,830	61,862
		475 × — 355 ×	111 24	= 44,205		420 ×	24	= 10,080		
					13,222				2,519	40,372
		495 × — 375 ×	61 8	= 27,195		440 ×	8	= 3,520		
					4,201				326	11,223
		505 × — 385 ×	36 0	= 18,180		450 ×	0	= 0		
		Total up to 120 feet ...			204,022					
		,, above ,, ,, ...			214,068					
Total...	444,127				418,090			Total ...	232,441	2,416,885

Table II.—*Abstract showing amount of Work to be executed in each Season.*

	To be executed by silting.					To be executed by manual labour.	Total.
	From Right Bank.		From Left Bank.		Total executed by silting.		
	Below main channel.	Above main channel.	Below main channel	Above main channel.			
2nd Season.	Cub. yds.	Cub. yds.	Cub. yds.	Cub. yds.	Cub. yds.	Cub. yds.	Cub. yds.
Right bank up to 120 feet	26,762	303,215	......	......	329,977	60,753	390,730
Left bank up to 110 feet	......	......	232,674	109,942	342,616	53,487	396,103
	26,762	303,215	232,674	109,942	672,593	114,240	786,833
3rd Season.							
Right bank from 120 to 205 feet... ...	......	239,296	......	......	239,296	56,835	296,131
Left bank from 110 to 205 feet... ...	......	......	......	134,201	134,201	105,062	239,263
	......	239,296	......	134,201	373,497	161,897	535,394
4th Season.							
150 feet dam in central opening	280,676	84,008	66,695	12,748	444,127	......	444,127
Remainder of central opening up to 120 feet	28,585	44,235	47,565	64,689	185,074	18,948	204,022
	309,261	128,243	114,260	77,437	629,201	18,948	648,149
5th Season.							
Central opening ...	......	126,558	......	......	126,558	87,510	214,068
Opening over end of culvert	64,502	91,170	21,795	22,489	200,206	32,485	232,441
	64,502	217,728	21,795	22,489	326,764	119,995	446,509
Total...	400,525	888,482	368,729	344,069	2,002,055	415,080	2,416,885

Table III.—*Table showing amount of Earth available for Silting.*

Level at which earth can be brought to dam.	Right Bank.		Left Bank.		Level.	Right Bank.		Left Bank.	
	Below main channel.	Above main channel.	Below main channel.	Above main channel.		Below main channel.	Above main channel	Below main channel.	Above main channel.
	C. yds.	C. yds.	C. yds.	C. yds.		C. yds.	C. yds.	C. yds.	C. yds.
From 0 to 25 feet ...	171,000	2,000	213.000	94,000	100 to 125 feet...	4,000	174,000	13,000	78,000
25 to 50 ,, ...	117,000	25,000	134,000	86,000	125 to 150 ,, ...	...	139,000	...	76,000
50 to 75 ,, ...	95,000	135,000	82,000	86,000	above 150 ,, ...	...	327,000	...	53,000
75 to 100 ,, ...	37,000	96,000	42,000	76,000					

TABLE IV.—*Quantities in temporary rough Stone Dams.*

Level above datum.	Upper.				Lower.				
	Length.	Breadth.	Area of section.	Content.	Length.	Breadth.	Area of section.	Content.	Total Content.
Feet.	Feet.	Feet.	Sq. ft.	C. yds.	Feet.	Feet.	Sq. ft.	C. yds.	C. yds.
0	178 ×	66	= 11,748	1,305	205 ×	66	= 13,530	1,503	2,808
5	188 ×	46	= 8,648	1,889	212 ×	46	= 9,752	2,156	4,045
10	198 ×	26	= 5,148	1,277	218 ×	26	= 5,668	1,428	2,705
15	208 ×	6	= 1,248	592	225 ×	6	= 1,350	742	1,334
			Total ...	5,063			Total ...	5,829	10,892

TABLE V.—*Quantities of Stone Revetment.*

Mean length.	Mean breadth (height).	Area.	Area.	—
Feet.	Feet.	Sq. ft.	Sq. yds.	
816 ×	$\frac{78+64}{2}$	= 57,936		Left side of central opening.
110 ×	$\frac{78}{2}$	= 4,290		
135 ×	$\frac{64}{2}$	= 4,320	7,394	
586 ×	$\frac{39+24}{2}$	= 18,453		Right do. do. (over culvert).
55 ×	$\frac{39}{2}$	= 1,072½		
17½ ×	$\frac{24}{2}$	= 210	2,193	
$\frac{287+207}{2}$ ×	71	= 17,537	....	Right side of opening below culvert.
$\frac{287+207}{2}$ ×	71	= 17,537	....	Left do. do. do.
$\frac{40+140}{2}$ ×	86	= 5,680	5,639	Rear slope of dam above end of do.
— 40 ×	52			
1,265 ×	101	= 127,765	14,196	Front slope of dam from 151 to 196 foot level.
358 ×	133	= 47,614	5,290	Rear do. do. from 2 to 40 do.
		Total ...	34,712	

TABLE VI.—*Quantities in Culvert.*

Number.	Length.	Breadth or thickness.	Height.	Content.	—
	Feet.	Feet.	Feet.	C. feet.	
	658	× 43	× 27½	= 778,085	Culvert.
3	× 658	× 9	× 20½	} = 427,042	Deduct for opening up to springing of arches.
3	× 658	× s. f. 31⅚		}	Do. do. above do.
				351,043	
4	× 9	× 4	× 27½	= 3,960	Projecting portion of piers at upper end.
4	× 667	× 5	× 4	= 53,360	Foundation of piers.
43	× 43	× 3	× 3	= 387	Cross retaining wall at lower end.
2	× 19	× 4	× 21	= 3,192	Side do. do. do.
2	× 18	× 2	× 7	= 504	Do. do. do. do.
2	× 19	× 5	× 4	= 760	Foundation of side retaining walls.
2	× 18	× 3	× 2	= 216	Do. do. do. do.
			Total	... 413,422	Portland cement concrete.
				54,336	Trenching rock for foundation.

TABLE VII.—*Quantities in silting Dams.*

CHINNA MOOLLYAR.				AVINASHI STREAM.				
Length.	Height.	Thickness.	Content.	Length.	Height.	Thickness.	Content.	—
Feet.	Feet.	Feet.	C. Feet.	Feet.	Feet.	Feet.	C. Feet.	
103	× 2½	× 5	1,287½	120½	× 2½	× 4	= 1,205	Dam.
94½	× 2½	× 6	1,417½	107	× 2½	× 5	= 1,337½	Dam.
85½	× 2½	× 7	1,496¼	90	× 2½	× 6	= 1,350	Dam.
77	× 2½	× 8	1,540	68	× 2½	× 7	= 1,190	Dam.
58	× 2½	× 9	1,305	...	...	...	.....	Dam.
45	× 4	× 11	1,980	57	× 4	× 9	= 2,052	Foundation in bed of stream.
76	× 2½	× 3	570	...	...	...	......	Wing wall to protect head of channel.
73½	× 2½	× 3½	643⅛	...	...	...	......	Wing wall to protect head of channel.
70	× 2½	× 4	700	59	× 2½	× 3	= 442½	Wing wall to protect head of channel.
67½	× 2½	× 4½	759⅜	46½	× 2½	× 3½	= 406⅞	Wing wall to protect head of channel.
47	× 2½	× 5	587½	38½	× 2½	× 4	= 385	Wing wall to protect head of channel.
40	× 2½	× 5½	550	21½	× 2½	× 4½	= 239⅜	Wing wall to protect head of channel.
33	× 2½	× 6	495	15	× 2½	× 5	= 187½	Wing wall to protect head of channel.
26	× 2½	× 6½	422½	...	...	...	......	Wing wall to protect head of channel.
19	× 2½	× 7	332½	...	...	...	......	Wing wall to protect head of channel.
			14,086¼	...	...	...	8,795¾	Total Portland cement concrete
			3,800	...	...	...	2,967	Trenching rock for foundations.
32	21 inches diameter		......	30	21 inches diameter		......	Earthen pipe.

TABLE VIII.—*Quantities in Escape.*

Distance from west end of escape.	Rock. Area of section.	Rock. Content.	Earth. Area of section.	Earth. Content.
Feet.	Sq. ft.	C. yds.	Sq. ft.	C. yds.
100	2,035	3,769	649	1,202
200	1,942	7,365	1,020	3,091
300	1,603	6,565	1,086	3,900
400	1,588	5,909	822	3,533
500	6,595	15,154	2,039	5,298
600	9,780	30,324	5,009	13,052
700	12,092	40,504	2,567	14,030
800	8,222	37,619	2,066	8,580
900	6,942	28,081	1,019	5,713
1,000	5,838	23,667	1,032	3,798
1,100	1,583	13,743	1,161	4,061
1,200	643	4,022	963	3,933
1,300	....	953	106	1,980
Total ...		217,675	...	72,171

NOTE.—The earth removed from the escape will be used in the construction of the dam, but as it will not be required for the latter until some time after, it must be removed from the former; it is necessary to provide for removing it by manual labour, as well as for transporting it to the dam by silting.

TABLE IX.—*Quantities in cutting through Water-shed.*

Distance from Water-shed line.		Rock. Area of section.	Rock. Content.	Earth. Area of section.	Earth. Content.
Feet.		Sq. ft.	C. yds.	Sq. ft.	C. yds.
South	900	111	308	40	183
	600	238	1,939	72	622
	300	323	3,117	100	956
North	0	411	4,078	53	850
	300	504	5,083	79	753
	600	92	3,311	24	572
			153		64
Total...		......	17,989	......	3,980

TABLE X.—*Quantities in Sluice Dam on Water-shed.*

Length.	Height.	Thickness.	Content.	Number.	Length.	Height.	Thickness.	Content.	——
Feet.	Feet.	Feet.	C. Feet.		Feet.	Feet.	Feet.	C. Feet.	
135½ ×	5 ×	5 =	3,387½		48 ×	14 ×	16 =	10,752	Lower part of dam.
126 ×	5 ×	6 =	3,780	3 ×	10 ×	6¾ ×	16		Deduct for opening up to springing of arches.
115 ×	5 ×	7 =	4,025	3 ×	$\frac{10^2\ \pi}{8}$		× 16	6,935	Do. do. above do.
102 ×	5 ×	8 =	4,080	3 ×	$\frac{(14^2-10^2)\pi}{8}$		× 16		Do. do. archwork.
86 ×	5 ×	9 =	3,870					3,817	
67 ×	5 ×	10 =	3,350	2 ×	7 ×	4 ×	18 =	1,008	Foundation of piers.
Total Portland cement concrete ...		...	22,492½	2 ×	5 ×	4 ×	18 =	720	
								5,545	Total cut-stone in cement.
				3 ×	$\frac{(14^2-10^2)\pi}{8}$		× 16 =	1,810	Archwork of do. do.
								5,207	Trenching rock for foundations.

TABLE XI.—*Quantities in Bridges on Road and Ghaut.*

Number.	Length.	Height.	Breadth or Thickness.	Content.	——
	Feet.	Feet.	Feet.	C. Feet.	*1st Class.* (Sairveyellar stream, Palgatchemadu stream, and two streams at foot of ghaut.)
2 ×	$\frac{18+54}{2}$ ×	12 ×	3 =	2,592	Piers.
2 ×	54 ×	3 ×	4 =	1,296	Foundations.
		Total Masonry...		3,888	
				1,296	Trenching rock for foundations.
	18 ×		12 =	(Sq. feet.) 216	Superstructure of timber, bamboos, and earth.

TABLE XI.—(Concluded.)

Number.	Length.	Height.	Breadth or Thickness.	Content.	——
	Feet.	Feet.	Feet.	C. Feet.	*2nd Class.* (10 Streams.)
2 ×	$\frac{18+36}{2}$ ×	6 ×	$2\frac{1}{2}$ =	810	Piers.
2 ×	36 ×	2 ×	3 =	432	Foundations.
		Total Masonry...		1,242	
				432	Trenching rock for foundations.
	18 ×		8 =	(Sq. feet.) 144	Superstructure.
					3rd Class. (15 Streams.)
2 ×	$\frac{18+30}{2}$ ×	4 ×	2 =	384	Piers.
2 ×	30 ×	$1\frac{1}{2}$ ×	$2\frac{1}{2}$ =	225	Foundations.
		Total Masonry...		609	
				225	Trenching rock for foundations.
	18 ×		6 =	(Sq. feet.) 108	Superstructure.

HAMPTON COURT,
14*th November* 1870.

(Signed) J. PENNYCUICK, Captain, R. E.,
Executive Engineer.

I.—DATA FOR ESTIMATING COST OF LABOUR.

		RS.	A.	P.
1,000 Coolies for 25 working days, at 8 Annas per diem	... ...	12,500	0	0
25 Maistries do. do. 1 Rupee do.	... ...	625	0	0
120 Sick men do. do. 4 Annas do.	... ...	750	0	0
3 Do. Maistries do. do. 8 ,, do.	... ...	37	8	0
Hutting for 1,120 men, at Rs. 4-8-0 } Per season of eight months.	...	630	0	0
Do. for 28 maistries, at ,, 6-0-0 } Per season of eight months.	...	21	0	0
Warm clothing for 1,120 men, at ,, 3-0-0 } Per season of eight months.	...	420	0	0
Do. for 28 maistries, at ,, 4-0-0 } Per season of eight months.	...	14	0	0
Total cost of 1,000 men per month of 25 working days...		14,997	8	0
Do. 1 man do. do.	...	14	15	11·5
Do. 1 ,, per day	...	0	9	7·18
		(= 10 Annas nearly.)		

Other labour to be calculated in proportion, 25 per cent. being added to the actual rate of daily pay on account of sick men, maistries, warm clothing, etc.

II.—Data for estimating cost of Earth-work by Silting Process.

For attending to 12 miles of main channel, at 5 coolies per mile ...	60 Coolies.
Do. do. branch channels	20 ,,
Do. do. dam	40 ,,
Excavating 3,600 cubic yards of earth, at 10 cubic yards per man ...	360 ,,
Total labour for executing 3,600 cubic yards of earth-work...	480 ,,
Cost of do. at 10 Annas per cooly... ... Rupees...	300

3,600 cubic yards for Rupees 300 = 12 cubic yards for one Rupee, or Rupees 0-1-4 per cubic yard.

III.—Data for estimating cost of Earth-work by Manual Labour.

		RS.	A.	P.
Excavating 1,000 cubic yards of earth ...	250 coolies, at 10 Annas ...	156	4	0
Clearing stones, roots, etc.	30 do. do. ...	18	12	0
Loading waggons...	125 do. do. ...	78	2	0
Unloading, spreading, ramming, etc. ...	75 do. do. ...	46	14	0
Laying and re-laying rails	6 carpenters, at Rs. 1¼ ...	7	8	0
Do. do.	40 coolies	25	0	0
Transport to dam 160 bullocks, at Rupee 1		160	0	0
Total cost of 1,000 cubic yards of earth...		492	8	0
Do. 1 do. do. ...		0	7	10·56

(= 8 Annas nearly.)

IV.—Data for estimating cost of Portland Cement Concrete.

(a.)—*Cement.*

	RS.	A.	P.
Cost of cement in England, £ 1-12-6 per ton	16	4	0
Freight to Negapatam	25	0	0
Carriage from Negapatam to the Perryaur	40	0	0
Total cost per ton...	81	4	0

(b.)—*Sand and Shingle.*

Excavating 24 cubic yards, 6 coolies, at 10 Annas	3	12	0
Transport to site of dam, one boat's crew of 4 men, at 10 Annas ... (Four trips per day, 6 cubic yards at each trip.)	2	8	0
Total for 24 cubic yards ..	6	4	0
Do. 1 do. ...	0	4	2

(c.)—*Broken Stone.*

The stone removed for forming the escape will be used for the concrete. It will be broken up by machinery driven by water power; the only expense will therefore be the pay of two men to look after the machine, and the cost of transporting the stone from the escape to the dam.

4 Annas per cubic yard will cover this.

(d.)—Labour for mixing and laying.

The concrete will be mixed by machinery driven by water power. One machine will manufacture 80 cubic yards in a day of 9 hours, the cost of which will be as follows :—

	RS.	A.	P.
Loading machine, spreading, etc., 12 coolies, at 10 Annas	7	8	0
Working and superintending machine, 2 men, at Rupees $1\frac{1}{4}$	2	8	0
Total for 80 cubic yards or 2,160 cub. feet...	10	0	0
290 cubic feet of concrete, weighs 27,550 lbs. at Rs. 81-4-0 per ton ...	1,023	9	8
580 do. sand ... ... at ,, 0-4-2 per cub. yd.	5	9	6
580 do. shingle ... ... at ,, 0-4-2 do. ...	5	9	6
1,450 do. broken stone ... ... at ,, 0-4-0 do. ...	13	6	10
Labour for mixing, laying, etc.	10	0	0
Centering, framing, etc.	21	12	6
Total cost of 2,160 cubic feet of concrete...	1,080	0	0
Do. 1 cubic foot do. ...	0	8	0

V.—Data for estimating cost of Silting Channels.

(a.)—Right bank, fed from Chinna Moollyar.

Breadth at top 6 feet, depth 2 feet, side slopes $\frac{1}{2}$ to 1. Channel to be entirely in excavation, the earth thus removed to be formed into an embankment on the outside. The natural slope of the ground being taken at an average of 3 to 1 ; area of section to be excavated will be $\frac{1}{2} \times (6+4) \times 2 + \frac{1}{2} \times \frac{2}{5} \times 6 \times 6 = 10 + 7\frac{1}{5} = 17\frac{1}{5}$ square feet or $51\frac{3}{5}$ cubic feet (= 2 cubic yards nearly) per yard of channel. 2 cubic yards at 4 Annas = 8 Annas.

(b.)—Left bank, fed from Avinashi Stream.

Breadth at top 5 feet, depth 2 feet ; area of section to be excavated $= \frac{1}{2} \times (5+3) \times 2 + \frac{1}{2} \times \frac{2}{5} \times 5 \times 5 = 8 + 5 = 13$ square feet or 39 cubic feet (= $1\frac{1}{2}$ cubic yards nearly) per yard of channel. $1\frac{1}{2}$ cubic yards at 4 Annas = 6 Annas.

Clearing ground (both banks), 1 Anna per yard.

Bamboo trestles and wooden troughs for crossing ravines, 5 Rupees per yard.

VI.—Data for estimating cost of Blasting.

	RS.	A.	P.
750 Miners, at 15 Annas per diem	703	2	0
400 Coolies, at 10 ,, do.	250	0	0
720 lbs. of powder, at 6 Annas per lb.	270	0	0
1,600 yards of match, at $\frac{1}{4}$ Anna per yard	25	0	0
60 lbs. of steel, at 8 Annas per lb.	30	0	0
800 ,, of iron, at 2 do.	100	0	0
8 Carpenters, at Rupees 1-4-0 each	10	0	0
8 Smiths, at do. do.	10	0	0
1 month's work of a forge	50	0	0
Sundries	51	14	0
Total cost of blasting and removing 1,000 cubic yards...	1,500	0	0
Do. do. do. 1 cubic yard ...	1	8	0

Note.—The above charges are for the escape. For the blasting in the cutting through the water-shed and on the road, 4 Annas per cubic yard extra has been allowed, as the conditions are not so favourable for getting out the rock in large quantities.

Hampton Court,
14th November 1870.

(Signed) J. PENNYCUICK, Captain, R.E.,
Executive Engineer.

ESTIMATES.

I.—*Silting Apparatus and Channels.*

Quantity.	—	Rate.	Amount.	Total.
	(a.)—Right Bank.	RS. A. P.	RS. A. P.	RS. A. P.
14,086 c. f. ...	Portland cement concrete ...	0 8 0	7,043 0 0	
3,800 ,, ...	Trenching rock for foundations...	0 2 0	475 0 0	
32 r. f. ...	21 inches earthen pipe	8 0 0	256 0 0	
	Total for Dam...	....	7,774 0 0	
......	Reservoirs for storing water ...	....	5,000 0 0	
7,883⅓ yds. ...	Main channel	0 9 0	4,434 6 0	
12,000 ,, ...	Branch channels	0 1 0	750 0 0	
450 ,, ...	Trestles, etc., for crossing ravines.	5 0 0	2,250 0 0	
......	Repairs (40 per cent. on main channel)	....	2,673 12 0	
......	Blasting, puddling, contingencies, etc.	....	1,117 14 0	
				24,000 0 0
	(b.)—Left Bank.			
8,796 c. f. ...	Portland cement concrete ...	0 8 0	4,398 0 0	
2,967 ,, ...	Trenching rock for foundations...	0 2 0	370 14 0	
30 r. f. ...	21 inches earthen pipe	8 0 0	240 0 0	
			5,008 14 0	
......	Reservoirs for storing water ...	....	3,000 0 0	
11,520 yds. ...	Main channel	0 7 0	5,040 0 0	
8,000 ,, ...	Branch channels	0 1 0	500 0 0	
480 ,, ...	Trestles, etc., for crossing ravines.	5 0 0	2,400 0 0	
......	Repairs (40 per cent. on main channel)	....	2,976 0 0	
......	Blasting, puddling, contingencies, etc.	....	1,075 2 0	
				20,000 0 0
......	Machinery for raising water ...	....	....	50,000 0 0
	Total...	....	....	94,000 0 0

II.—*Dam and Culvert.*

Quantity.	—	Rate.	Amount.	Total.
	(a.)—Dam.	RS. A. P.	RS. A. P.	RS. A. P.
2,001,805 c. y.	Earth executed by silting ...	0 1 4	1,66,817 1 4	
415,080 ,, ...	Do. by manual labour ...	0 8 0	2,07,540 0 0	
10,892 ,, ...	Rough-stone for temporary dams.	0 8 0	5,446 0 0	
34,712 s. y.	Do. for revetment ...	0 10 0	21,695 0 0	
800,000 ,, ...	Clearing ground...	0 0 3	12,500 0 0	
				4,13,998 1 4
	(b.)—Culvert.			
413,422 c. f.	Portland cement concrete ...	0 8 0	2,06,711 0 0	
54,336 ,, ...	Trenching rock for foundations...	0 2 0	6,792 0 0	
1,500 s. f.	Timber framing for closing arches	1 8 0	2,250 0 0	
				2,15,753 0 0
......	Tools, plant, and machinery ...	... .	....	89,600 0 0
......	Sundry charges, contingencies, etc.	....	....	67,648 14 8
	Total...	....	....	7,87,000 0 0

III.—*Escape.*

Quantity.	—	Rate.	Amount.	Total.
		RS. A. P.	RS. A. P.	RS. A. P.
217,675 c. y....	Blasting and removing rock ...	1 8 0	3,26,512 8 0	
72,171 ,, ...	Removing earth	0 4 0	18,042 12 0	
......	Tools, plant, and machinery ...	....	20,400 0 0	
......	Sundry charges, contingencies, etc.	....	15,044 12 0	
	Total...	... .	....	3,80,000 0 0

IV.—*Cutting through Water-shed and Sluice Dam.*

Quantity.	—	Rate.	Amount.	Total.
	(a.)—Cutting.	RS. A. P.	RS. A. P.	RS. A. P.
17,989 c. y. ...	Blasting and removing rock ...	1 12 0	31,480 12 0	
3,980 ,, ...	Removing earth	0 4 0	1,995 0 0	33,475 12 0
	(b.)—Sluice Dam.			
22,492½ c. f. ...	Portland cement concrete ...	0 8 0	11,246 4 0	
5,545 ,, ...	Cut-stone in cement	0 12 0	4,158 12 0	
1,810 ,, ...	Archwork of cut-stone in cement.	1 0 0	1,810 0 0	
5,207 ,, ...	Trenching rock for foundations...	0 2 0	650 14 0	17,865 14 0
......	Tools, plant, and machinery ...	....	....	2,200 0 0
......	Sundry charges, contingencies, etc.	....	....	2,458 6 0
	Total...	....	....	56,000 0 0

V.—*Road.*

Quantity.	—	Rate.	Amount.	Total.
	(a.)—Road from foot of Ghaut to site of Dam.	RS. A. P.	RS. A. P.	RS. A. P.
7,339 yds. ...	Clearing ground (thick jungle)...	0 1 6	688 0 6	
8,917 ,, ...	Do. do. (small do.) ...	0 1 0	557 5 0	
17,932 c. y....	Excavating earth	0 4 0	4,483 0 0	
4,835 ,, ...	Do. gravel and small stones.	0 5 0	1,510 15 0	
6,644½ ,, ...	Blasting and removing rock ...	1 12 0	11,627 14 0	
55,999½ ,, ...	Large boulders requiring blasting.	0 12 0	41,999 10 0	
22,388½ ,, ...	Do. do. do. ...	0 8 0	11,194 4 0	
6,980 ,, ...	Do. not requiring blasting.	0 6 0	2,617 8 0	
9,904 ,, ...	Embankment (earth)	0 8 0	4,952 0 0	
1,130 ,, ...	Dry-stone revetment walls ...	1 0 0	1,130 0 0	

Quantity.	——	Rate.	Amount.	Total.
		RS. A. P.	RS. A. P.	RS. A. P.
16,256 yds ...	Drains along inside of road ...	0 0 3	254 0 0	
16,256 ,, ...	Metalling 12 feet broad ...	0 8 0	8,128 0 0	89,142 8 6
	Bridges (1st Class.)			
3,888 c. f....	Rubble masonry in chunam ...	0 4 0	972 0 0	
1,296 ,, ...	Trenching rock for foundations...	0 2 0	162 0 0	
216 s. f....	Superstructure	0 6 0	81 0 0	
......	Four bridges each	....	1,215 0 0	4,860 0 0
	Bridges (2nd Class.)			
1,242 c. f....	Rubble masonry in chunam ...	0 4 0	310 8 0	
432 ,, ...	Trenching rock for foundations.	0 2 0	54 0 0	
144 s. f....	Superstructure	0 6 0	54 0 0	
......	Ten bridges each	....	418 8 0	4,185 0 0
	Bridges (3rd Class.)			
609 c. f....	Rubble masonry in chunam ...	0 4 0	152 4 0	
225 ,, ...	Trenching rock for foundations...	0 2 0	28 2 0	
108 s. f....	Superstructure	0 6 0	40 8 0	
......	Fifteen bridges each	....	220 14 0	3,313 2 0
				1,01,500 10 6
	(b.)			
2,800 yds....	Branch roads about site of dam.	1 4 0	3,500 0 0	
4,000 ,, ...	Footpaths	0 8 0	2,000 0 0	5,500 0 0
	(c.)			
14,960 ,, ...	Road from Cumbum to foot of Ghaut	1 12 0	26,180 0 0	26,180 0 0
......	Tools, plant, and machinery ...	....	....	800 0 0
......	Sundry charges, contingencies, etc.	....	....	6,019 5 6
	Total...	....	....	1,40,000 0 0

VI.—*Buildings.*

Quantity.	——	Rate.	Amount.	Total.
		RS. A. P.	RS. A. P.	RS. A. P.
2,700 s. f. ...	Quarters for 3 Officers	2 8 0	6,750 0 0	
960 ,, ...	Office	2 8 0	2,400 0 0	
2,160 ,, ...	Quarters for 4 Overseers ...	2 4 0	4,860 0 0	
12,000 ,, ...	Hospital for 120 Coolies ...	2 0 0	24,000 0 0	
2,000 ,, ...	Do. for 20 Maistries or skilled workmen	2 0 0	4,000 0 0	
5,000 ,, ...	Workshops, sawpits, forges, storesheds, etc.	1 12 0	8,750 0 0	
540 ,, ...	3 Powder Magazines, each for 250 barrels	4 8 0	2,430 0 0	53,190 0 0
......	Repairs 8 per cent. for 5 seasons.	....	....	21,276 0 0
... ..	Sundries...	....	....	534 0 0
	Total...	....	....	75,000 0 0

VII.—*Establishment.*

	Rate.	Amount.	Total.
	RS.	RS.	RS.
2 Overseers for 40 months ...	100	8,000	
2 Do. for 24 do. ...	100	4,800	
2 Writers and Accountants for 40 months ...	40	3,200	
1 Do. do. do. for 40 do. ...	50	2,000	
1 Do. do. do. for 40 do. ...	60	2,400	
1 Medical Subordinate for 40 do. ...	100	4,000	
1 Do. do. for 24 do. ...	100	2,400	
28 Lascars for 40 months ...	10	11,200	
Total...	......	......	38,000

VIII.—*Preliminary Expenses.*

	RS.
Expenses of preliminary surveys and investigations	30,000

IX.—*Tools, Plant, and Machinery.*

	RS.	A.	P.	RS.	A.	P.
(a.)—Railway Materials.						
12,000 yards of rail, 9 lbs. to the yard, at Rupees 225 per ton.	10,848	3	5			
60,000 feet of sleepers, at Rupees 40 per 100 running feet ...	24,000	0	0			
5,000 dozen nails, 2½ lbs. to the dozen, at 3 dozens for 1 Rupee.	1,666	10	8			
60 waggons, at Rupees 400 each	24,000	0	0			
Maintenance and repairs, 25 per cent. ...	6,000	0	0			
Sundries ...	485	1	11			
				67,000	0	0
(b.)—Boats.						
6 sheet-iron boats with tackle, etc., at Rupees 2,000 each ...	12,000	0	0			
1 four-oared rowing boat ...	1,500	0	0			
2 pair oared do., at Rupees 800 each ...	1,600	0	0			
Maintenance and repairs, sundries, etc....	3,900	0	0			
				19,000	0	0
(c.)—Tools.						
Rock-cutting tools for 300 men, at Rupees 5 per man...	1,500	0	0			
Earth-work tools for 900 men, at Rupees 3 per man ...	2,700	0	0			
Carpenters' and Smiths' tools, workshop fittings, etc. ...	3,000	0	0			
Maintenance and repairs, 25 per cent. ...	1,800	0	0			
				9,000	0	0
(d.)—Lifting and hauling apparatus.						
4 1-ton cranes, at Rupees 850 each ...	3,400	0	0			
1 small pile-driving machine ...	800	0	0			
2 6-ton lifting and traversing jacks, Rupees 200 each...	400	0	0			
Maintenance and repairs, 25 per cent. ...	1,150	0	0			
Rope, chains and sundries ...	2,250	0	0			
				8,000	0	0
(e.)—Concrete-making apparatus.						
2 concrete-making machines, at £265 each ...	5,300	0	0			
1 stone-breaking machine, at £190 ...	1,900	0	0			
Carriage from London to the Perryaur, 12 tons, at Rupees 85 per ton ...	1,020	0	0			
Maintenance, repairs, etc. ...	1,780	0	0			
				10,000	0	0

	RS. A. P.	RS. A. P.
(*f.*)—*Apparatus for raising water.*		
2 thirty-horse power turbines, with pumps for raising 150 cubic feet per minute, at £480 each	9,600 0 0	
700 feet 15-inch delivery and suction pipe, at £0-16-6 per foot.	5,725 0 0	
1,200 feet 11-inch discharge pipe, at £0-11-0 per foot ...	6,600 0 0	
Bolts, bends, etc.	900 0 0	
1 fifteen-horse power turbine, with pumps for raising 75 cubic feet of water per minute, £280	2,800 0 0	
360 feet 11-inch delivery and suction pipe, at £0-11-0 per foot.	1,980 0 0	
600 feet 8-inch discharge pipe, at £0-7-4 per foot	2,200 0 0	
Bolts, bends, etc.	300 0 0	
Carriage of 120 tons from London to the Perryaur, at Rupees 85 per ton	10,200 0 0	
Fixing	4,000 0 0	
Repairs, maintenance, etc.	5,695 0 0	
		50,000 0 0
Total for Tools, Plant, Machinery, etc...	....	1,63,000 0 0

Distribution of the above charges.

——	(*a.*)	(*b.*)	(*c.*)	(*d.*)	(*e*)	(*f.*)	Total.
	RS.	RS.	RS.	RS.	RS.	RS.	RS.
Dam and Culvert	49,000	19,000	4,600	7,000	10,000	......	89,600
Escape	16,000	......	3,400	1,000	......	......	20,400
Cutting	2,000	......	200	......	......	......	2,200
Road	......	......	800	......	......	......	800
Silting apparatus	......	......	......	......	......	50,000	50,000
Total...	67,000	19,000	9,000	8,000	10,000	50,000	1,63,000

Abstract Estimate for Head Works.

	RS.
I.—Silting apparatus	94,000
II.—Dam and Culvert	7,87,000
III.—Escape	3,80,000
IV.—Cutting through Water-shed...	56,000
V.—Road	1,40,000
VI.—Buildings...	75,000
VII.—Establishment	38,000
VIII.—Preliminary expenses	30,000
Total...	16,00,000

HAMPTON COURT,
14*th November* 1870.

(Signed) J. PENNYCUICK, Captain, R.E.,
Executive Engineer.

MEMORANDUM.

In the project for the diversion of the Perryaur, forwarded by me on the 14th November, it was proposed to place the top of the dam at 205 feet above datum, and the crest of the escape at 174 feet, which would make the ordinary level of the

lake about 163 or 164 feet. These levels were chosen not only as being the most economical, but chiefly as allowing the work to be executed in the least possible time, as the time required for the construction of the escape and dam would be about equal.

2. I have since learnt that it is in contemplation to fix the ordinary level of the lake at about 200, which would bring the escape crest to 210, and the top of the dam to 240. In this case it would, of course, be necessary to build the dam on site No. 3, not, as proposed by me, on No. 2.

3. The cost of the escape in this case would not differ materially from that of the upper site at the 174 feet level.

4. The dam would contain 3,486,800 cubic yards of earth, of which 2,017,300 could be executed by silting, the remainder having to be done by manual labour.

5. In my estimates the cost of the earth-work (by manual labour) has been taken at 8 Annas per cubic yard, but this would be greatly increased if the dam had to be raised to 240 feet, owing to the increased distance from which the earth would have to be brought.

6. I believe I shall not be over-estimating the cost in adopting the following rates :—

Up to 180 feet	8 Annas per cubic yard.
From 180 to 210 feet	10 ,, ,, ,,
From 210 to 240 ,, ...	12 ,, ,, ,,

7. From these data it is found that the cost of the earth-work of the dam would be Rupees 9,99,800 against Rupees 3,68,000 for the 205 feet dam on site No. 2.

8. In addition to this there would be an increase of 119 feet in the length of the culvert; the dam being thicker at the base and longer at the top, the area of stone revetment would be greater, and more ground would have to be cleared for the excavation of earth. These, with minor items, would add a further sum of about Rupees 70,000 to the cost of the dam.

9. The gap in the water-shed ridge would require a dam with a maximum height of 70 feet, and this would cost Rupees 1,70,000 against Rupees 56,000, the estimated cost of the cutting and sluice dam for the lower level.

10. The charges for contingencies, repairs, and maintenance of buildings, tools and plant, and for establishments, would also be largely increased, and altogether the cost of the head-works would be raised from Rupees 16,00,000 to Rupees 26,00,000.

11. The additional amount of labour required (allowing for materials, tools, etc.,) is nearly that of 1,200 coolies for 1,000 days.

12. In my calculations I have assumed 1,200 as the greatest number of coolies likely to be available for work at one time; the extra labour required will therefore be that of our whole available force for 1,000 working days, that is, for five seasons; this involves a postponement of the completion of the works for five years, and a sacrifice of revenue to the amount of 27½ lacs of Rupees.

13. The sole advantage to be gained by this raising of the lake level is the storage of more water during floods.

14. The quantities stored between the normal level of the lake and that of the escape crest would be—

For the 200 feet level	26,711 cubic yards.
For the 164 feet do.	39,008 " "

Between the normal lake level and the maximum level during an excessive flood—

For 200 feet	1,06,927 cubic yards.
For 164 feet	77,020 " "

That is to say, that the higher level would allow 12,397,000 cubic yards more to be thrown into the lake before any water passed over the escape, and that during an excessive flood, such as may perhaps be looked for once in twenty years, the higher level will waste 29,807,000 cubic yards less than the lower one.

15. For freshes smaller than that given in my Table No. 4, the one level would be as good as the other.

16. We have at present only one year's observations of the actual discharge of the river; during this year there was only one flood which would have passed over the escape for the lower level, and in this case the saving of water would have been the amount stated above (29,807,000 cubic yards). In ordinary years such a flood as this would not be likely to occur, but there might be two or three smaller ones. It is probably taking a high estimate to say that in an average year the amount of water saved by the use of the higher level would amount to 30 millions of cubic yards.

17. The effect of this increased storage will merely be that the lake will take a little longer in falling to its proper level after a flood; that is, that the high discharge through the cutting produced by the rise of the lake will last a few days longer with the larger lake than with the smaller one. This discharge varies from 675,000 cubic yards per hour at escape crest level to 1,100,000 at maximum flood level (190 feet), and is probably considerably more than the channels from the Vigay and Sooroolly (neither of which rivers is likely to be very low when the Perryaur is in flood), can carry off; any addition to it, or increase in its duration, will therefore merely cause more water to pass down the Vigay into the sea, where it will be as much wasted as if it went over the escape into the Perryaur.

18. In point of fact, the effect of raising the lake level from 164 feet to 200 feet would seem to be this: that in an average year some 30 millions cubic yards of water will go down the Vigay into the Bay of Bengal instead of down the Perryaur into the Arabian sea—a somewhat inadequate return for $37\frac{1}{2}$ lacs of Rupees.

19. I have hitherto said nothing about the increased difficulty (as distinguished from cost) of constructing a dam 240 feet high; but this is a point which cannot be overlooked.

20. I believe the 205 feet dam proposed by me to be thoroughly practicable, but to be very near the maximum limit. If the time required for the construction of the escape could be reduced, I should be very willing to lower the levels five or ten feet; but I should be very doubtful of the wisdom of raising them. All the

difficulties to be encountered increase so much with any increase in the height of the dam that I question very much whether a dam 240 feet high would ever be completed at all.

21. I should certainly be extremely unwilling to have anything to do with its execution, while nothing would give me greater pleasure than to be employed in carrying out the scheme proposed in my former report.

HAMPTON COURT PALACE, (Signed) J. PENNYCUICK, Captain, R.E.,
30th December 1870. *Executive Engineer.*

Recd 14th November by No 279

" 12th May — 170 — 183

" 9th Novr ——— 149

Public Works 1871 Department
Proce of Govt for May
(115) No 1665

From
The Chief Engr
for Irrigation

To
The Secretary to Govt
P.W.D.

Dated 28th Feb
Recd 12th April 1871
Regd 13 "

No 56.

Enclosure one

Note on Captain Pennycuick's designs & estimates for the Periyaur project head works.

No 1236 - 4 May 1871.

Copy

R.C. 20th June 1871 R-22W

C 14th Apl 71 R-198

Proceeding ... *us Government, Public Works Department,*
14th November 1867.

No. 279. Read the following letter from the Superintending Engineer of the 1st Division :—

(Here enter 7th August 1867.)

No. 280. ORDER THEREON, 14th November 1867, No. 3,521.

IRRIGATION, No. 14.

1. The report now before the Government contains a sketch of the operations which Captain Ryves considers necessary for conveying the waters of the Perriar river to the low lands of Madura.

2. The project is in two sections :—

First.—The construction of a dam across the Perriar to raise the water to such a height, as, with the addition of a moderate amount of cutting through a rocky saddle, to allow of its being turned into the Sooroolly, and thence into the Vigay river.

Second.—The distribution of the supply thus thrown into the Vigay for the irrigation of three talooks in Madura, partly by means of existing channels and tanks, and partly by new channels.

3. Captain Ryves furnishes a tolerably complete account of the present state of the Madura district, of the insufficiency of water for the irrigation of the land under the channels leading from the Vigay, and of the extensive field available to the north of that river for the increase of wet cultivation. No argument seems to be required to prove either that the present supply of water in the Madura district is insufficient for the wants of the people, or that any addition to it would not be eagerly appropriated. It is estimated that a supply may be obtained from the Perriar competent to the irrigation of 149,000 acres of paddy, of which 78,000 acres would be first, and 71,000 second crop, and that the water rate yielded to Government would amount to 6 lacs of Rupees.

4. These figures may be relied on as approximately correct, seeing that they are the result of an intimate knowledge of the Madura district on the part of Captain Ryves. It has then to be decided whether the proposed works are practicable, and if the outlay required for their execution would be remunerative to the extent anticipated by the author of the project.

5. The project, as explained by Captain Ryves, is an old one. The people of Madura have long looked to it as the solution of their difficulties in regard to supplying their fields with water, and the Engineers of the district have been quite alive to its importance. It is only now, however, that it has been submitted in such a comprehensive manner as to allow the Government to form any opinion as to its general soundness.

6. Captain Ryves has conclusively shown that an excellent site can be obtained for the construction of a dam across the Perriar. The width of the river is less than 200 feet at the bed, and the banks rise rapidly to the height of 150 feet and upwards. At the height of 104 feet above the bed, a depression or saddle is available for conversion into an escape. The dam would intercept the drainage of 250 square miles of country which draws a supply from both monsoons. There have been no means of ascertaining with any degree of accuracy what amount of

rain actually falls over this tract, and Captain Ryves had therefore no alternative but to estimate it from the known rain-fall in the adjacent districts. The result he has thus arrived at is that the rain-fall may be estimated at 78·98 inches per annum, as the minimum, and that the average is more likely to be 100 inches.

7. Captain Ryves' estimate of the quantity of water discharged by the river at the site of the proposed work must also necessarily be but a very rough approximation at best. The maximum rate of discharge he estimates at 3½ millions of cubic yards per hour, or about 25,000 cubic feet per second, which quantity is equivalent to a fall of 3·7 inches of rain in 24 hours over the drainage basin of 250 square miles.

Appendix C.

8. At the close of the north-east monsoon the supply falls to 100,000 cubic yards per hour, or 700 cubic feet per second, and a still further diminution must take place with the continuance of dry weather for several months in succession.

9. A knowledge of the actual rain-fall over the drainage in question is doubtless of the highest importance both for a determination of the quantity of water which can confidently be calculated on for the supply of the Madura district, and for the control of the floods of the river during the construction of the dam. It would, however, be difficult if not impossible to ascertain with any high degree of accuracy the amount of rain-fall on the tract comprised within the present project. It can only be judged of by analogy, and the Government, taking into consideration the unfailing character of the south-west monsoon on the western ghauts and the abundant rain-fall along them at all points to which observation has extended, are satisfied that Captain Ryves' estimate of the supply available from the basin of the Perriar for distribution in Madura is extremely moderate.

10. From the site of the proposed dam to the water-shed of the drainages leading to the eastern and western coast the distance is only three and a half miles, and the highest point of the ridge is 165 feet above the bed of the river at the site of the dam.

11. The ridge would have to be cut through, and it becomes a matter of calculation to what height it would be best to raise the dam in order to save cutting, or conversely, to what depth it would be expedient to carry the cutting in order to save height in the dam.

12. Captain Ryves has given the approximate relative cost of dam and cutting at the different levels at which it would be economically practicable to draw off the required supply of water to Madura. As rock is encountered at a short depth below the surface, and as the length of the cutting would increase as the depth increased, there must be a limit beyond which it becomes more economical to raise the water artificially than to continue the excavation of a channel. The details of Captain Ryves' computation of the relative cost of dam and cutting at different levels are not furnished, and before any design could be finally approved by Government they would require a detailed calculation, with a complete record of the levels of the ground, in support of the conclusion arrived at, that one particular level for draining off the supply of water is better than any other that could be proposed.

13. Assuming for the present that Captain Ryves' figures are approximately correct, the Government learn that if the water were drawn off towards Madura at a level of 105 feet above the bed of the river at the site of the dam, or in other words, if a dam of that height, *plus* the height at which the crest of such a work must be above the water level, were constructed, the cutting through the rock would reach a maximum depth of 75 feet, and would cost upwards of 14 lacs of Rupees, and is computed to occupy fourteen years in execution; while the dam and escape would only cost 4 lacs. The other extreme given by Captain Ryves is at the 155 feet level, which would reduce the cost of cutting to half a lac of Rupees, and swell that of the dam and escape to 13¼ lacs. The level selected is at the height of 133 feet above the bed of the river at the dam, which gives a maximum cutting of about 45 feet. The level of 133 feet represents the computed normal water level. The crest of the escape is fixed at the 142½ feet level, or about 40 feet above the lowest point of the saddle adjoining the dam, and the extreme level to which an extraordinary flood is computed to rise would be 7½ feet higher.

14. The proposed dam would thus have to withstand a de[illegible] 150 feet of water. There is no similar work in existence which retains a body of water much exceeding 100 feet in depth, and, considering the difficulties under which it would have to be raised in a tract of country covered with dense forest and elephant grass, and possessing a character for extreme unhealthiness in certain months which would doubtless deter workmen from giving their services, excepting under greatly enhanced rates; looking also to the stoppage of the work during the unhealthy season, and to other causes of delay which cannot fail to arise, the Government are well aware that nothing short of a well founded conviction of the final success of the undertaking would justify them in supporting it.

The reservoir of St. Ferréol holds a depth of water of 106 6 feet.

15. Captain Ryves has clearly shown that the diversion of the Perriar waters into Madura would be an inestimable boon to the inhabitants of that district, and he has also satisfied the Government that a large outlay might be incurred for this purpose with great advantage to the revenue. What the Government still require is an assurance that the mode of bunding the Perriar proposed by Captain Ryves, and the height which he has determined upon as the most suitable for the delivery of the water across the water-shed, are really the best that can be devised. The construction of a dam to retain 150 feet depth of water is a formidable undertaking. It must be therefore matter for careful consideration whether security should not be purchased by a larger outlay in the first instance than Captain Ryves contemplates, viz., by a reduction of the height of the dam and an addition to the rock cutting through the water-shed, even though the period occupied in carrying the work to completion may be materially extended in consequence.

16. These papers will therefore be returned to Captain Ryves in order that he may, taking the above remarks into consideration, re-submit his proposal for the construction of the dam. Although Captain Ryves' mode of carrying out that difficult work appears to have been thoroughly considered by him, the Government

fear that it is too complicated to prove practically successful, and are of opinion that some other manner of procedure which, combining simplicity with rapidity of execution would give a better assurance of a completely satisfactory result, should be adopted.

17. It seems to Government that there would be great danger in allowing any portion of the flood-water of the river to pass over the crest of the dam during its construction, and that the arrangements for conveying the water from the front to the rear of the work while in progress are open to serious objections. Not only would the transport from the coast of the massive portions of the iron syphons which Captain Ryves proposes to make use of be a matter of great difficulty, but the working of them, involving not simply erection in one spot, but removal from a lower to a higher level as the work proceeded, would require the command of a much greater amount of skilled labor than could be counted on. It has further to be observed that, if by any accident, the free discharge of the syphons were checked the water in the pool above the dam would rise and threaten the destruction of the w[illegible]

18. As the stone to be obtained from the cutting through the saddle will, it is believed, be for the most part got out in much smaller pieces than will be suitable for the construction of the dam, the expediency of obtaining stone from that source seems doubtful, and it will probably be preferable to procure all that may be required for the dam from the adjoining hills, throwing it in in large masses.

19. The project has not been submitted in the full, detailed, and comprehensive manner in which the Government of India now direct that all schemes requiring their sanction should be laid before them, and Captain Ryves will therefore report at once his views as to the measures that should be taken for completing the necessary surveys and levelling operations, as well as for collecting the additional information that is necessary to enable him to devise and complete the whole of the designs and estimates connected with the project, and to furnish the definite and copious explanations which the Government of India will expect to receive with it.

20. On the receipt of his report, which will be submitted through the Chief Engineer for Irrigation, the Government will endeavour to place at Captain Ryves' disposal for employment in Madura such establishment as may be requisite for the thorough preparation of the data he may require, and on its being ready, His Excellency in Council will authorize his return to Madura to finally put the project into a shape for submission to the Government of India.

21. The Government are determined that this ancient and interesting project on which so much intelligent and courageous labor has been expended by Captain Payne and Captain Ryves, and on which the welfare of a great district of country depends shall be finally and completely sifted. They will devote to it all the amount of inquiry and analysis which may be requisite to put it into the completest shape, in the earnest hope that the result may justify them in submit-

ting the scheme for the approval of the Government of India supported by the official sanction of those professional advisers whose opinion in a matter of this nature is so indispensable.

(True Extract.)

Colonel, R. E.,
Secretary to Government.

To Captain Ryves, R. E.
To the Superintending Engineer, 8th Division.
,, Controller of Public Works Accounts.
,, Revenue Department.

Exd. S. T. Augustin.

Read the following letter from Captain J. G. RYVES, R. E., Superintending Engineer, 1st Division, on special duty, to the Secretary to Government, Public Works Department, dated Camp at Chinnamanoor, Madura District, 7th August 1867 :—

1. In accordance with the Orders of Government, dated 16th January last, I have been engaged since the beginning of February in completing the investigation of the Perryaar project; and, having fully satisfied myself as to its feasibility, in working out its details and preparing the plans and estimates necessary to enable Government to apply for funds for its early execution, in case they consider that the feasibility of the project has been satisfactorily established.

2. Captain Payne, in conjunction with whom I was ordered to complete the investigations, which had already been well advanced by that Officer, worked with me till the end of March, when by the desire of the Superintending Engineer he took up the Tinnevelly Irrigation projects, the submission of which to Government without further delay was called for.

3. In the report which I have now the honor to submit, and in the drawings and estimates which accompany it, full particulars of the proposed works will be found; but I will here notice separately, as briefly as is consistent with clearness, the principal difficulties which will have to be surmounted.

4. The works proposed are simply a bund across the Perryaar valley, and a cutting through the water-shed; the latter being as regards engineering nothing more than an ordinary work, such as may be met with on almost any Railway of any length—the former being an extraordinary work both in the depth of water to be held up by it, and in the special difficulty of establishing a bund across a flowing river which cannot be diverted from its course while the work is being carried on.

5. But independent of all engineering difficulties, the execution of these head works will have to be undertaken under peculiarly unfavorable circumstances, arising from their situation in an uninhabited jungle country, 25 to 100 miles distant from where the labor will have to be brought, and bearing a bad reputation for fever.

6. The great popularity of the scheme among the influential portion of the agricultural community will no doubt be of great assistance to us in the matter of procuring the necessary number of workmen, but, to ensure a steady and certain supply it will be, besides, necessary to pay high wages, and to provide for the comfort of our workmen by housing them well, establishing a good bazaar and easy communication with the principal village in the adjacent low country, and a good Hospital with an experienced Medical Officer and adequate establishment of Medical subordinates. My estimates provide amply for all these requisites, excepting the staff pay of the Medical Officer which, as well as the pay of the Engineer Officers,

is not shown in them. The following are the rates of wages which I have adopted :—

	Rupees.
An ordinary cooly	10 to 12 per mensem.
Wagonmen	16 "
Miners	15 to 20 "
Smiths, set (with hammerman and bellows boy)	50
Carpenters	25 "
Stone-cutters	25 "
Bricklayers	20 "

25 Working days in each month.

These rates being more than double the regular Madura rates, and considerably above the Ceylon rates for Tamul labor will, I have no doubt, be sufficient to secure an adequate and steady supply of labor, but with a view to rapid execution of the head-works it will be advisable to employ besides a large gang of (say 250) convicts.

A Company of Sappers would be of great service especially on the cutting, and I trust that when the work is sanctioned, one will be detached for duty at the Perryaar.

7. Besides the obstacle which the remote situation of the works and the *fear* of fever will oppose to us, but which will, I have no doubt, be overcome under the influence of the popularity of the project, high wages and good treatment, we have to consider how the fever *itself* will affect the work. The unhealthiness of the Perryaar tract has, I have reason to believe, been much exaggerated. The Goodaloor jungle, at the southern extremity of the Cumbum valley, and at the foot of the hills, above and beyond which the Perryaar flows, is no doubt very unhealthy during the dry months of the year ; and although I have not heard of a single case of jungle fever which has been satisfactorily traced back to the Perryaar tract, most probably that tract is also unhealthy during March, April, and May, and till the south-west monsoon has set in. But from all that is known of the country, it appears to be quite free from the fever malaria from the commencement of the south-west monsoon in June till the end of February. Our working season in the hill tract would, therefore, commence in June, and on the 15th February we would stop work there, and transfer our workmen to the works on the Soroollyaar and the Vigay channels. If this limit to the working season be rigidly adhered to, and the workmen be supplied with good cumblies and comfortably housed in warm water-tight huts, erected on elevated breezy situations, I feel confident that the Perryaar fever would not touch us. Nevertheless, the Doctor should have *carte blanche* both as to the quantity and quality of quinine and bark, regardless of what it may cost.

8. The limit thus set upon our working season will of course add much to the cost of the undertaking, as we shall lose the best months for work in the bed of the river. And this brings me to the next difficulty, viz., (1) getting a footing for the work in the bed of the river, and (2) carrying it on in spite of floods, when we have no means of diverting the stream from its bed (hemmed in, as it is, on both sides by precipitous hills) until the water surface has been raised to the level of the saddle (E), which is 110 feet above the bed of the river.

9. This difficulty will be overcome with the aid of powerful syphons and by carrying on the earth and puddle-work *in front of a* stone-dam. The former to pass the river over the work during the eight or ten weeks that operations will go on in the river bed, and the latter to protect the surface of the work done from erosion by the current of the big freshes of the following rainy seasons. The proposed method is explained in sufficient detail in Appendix marked A. I should state, for the information of Government, that the use of syphons on a great scale in the way I propose is not a novel or untried expedient, for instance the bund across the great breach* in the Lincolnshire sea dyke was constructed under syphons. Having been an eyewitness of the success of the plan on that occasion, it occurred to me at the time that it would be peculiarly well adapted to meet our difficulty at the Perryaar.

* Of 1862.

10. The estimates (Nos. 2 and 3) for the bund and cutting being prepared in terms of labor and materials, will enable Government to judge whether the assumed rate of progress, daily and monthly, may be safely reckoned upon. 650 men for the bund and for the cutting 400, the bund party at work for five seasons, the cutting party for the first three only, is the strength I require to carry out the works in the time and at the cost shown in my report and estimates. If we find that we cannot command this moderate strength, we shall have to reduce the quantity of work set down for each season, and the work will take longer to complete, and cost more than my estimate. But by an unrestricted supply of convict labor to make good any deficiency in the required strength, the completion of the work in the estimated time at the estimated cost may be ensured. I would rather not have the convicts, and they should not be called in if we can in any way (not involving long delay in the completion of the works) do without them.

11. As regards the great depth of water to be held up by the bund, I see no reason for doubts of success, if only the bund be made sufficiently massive and be carefully constructed. The depth of water in front of the bund at the deepest point, measured from the bed of the river, will, in the ordinary state of the river, be about* 140 feet, and in floods from ten to sixteen feet higher. But before the bund is completed, the river channel in its front will be filled with silt to a height of *at least* 30 feet at the toe of the bund's front slope, and extending with gradually diminishing depth probably a mile and a half up the river bed, so that we shall be guarded against the most serious effect of the great depth, viz., percolation between the base of the bund and the rocky bed of the river, before that great depth exists to produce the effect. And this deposit in front will go on year by year adding to the security of the bund. Within three or four years after the completion of the bund the depth of water will be reduced from 110 feet to 60, and ultimately† there will be no lake at all but a flat valley, only inundated during high freshes, through which the Perryaar will flow to the cutting.

* In Spain there is a bund (masonry) which holds up a depth of water nearly as much as this. I know of no other bund retaining more than 100 feet depth of water.

† In our grand-children's time.

12. The only other obstacle to be got over is that arising from the head works being situated beyond the British frontier. As it happens, the ground (or at any rate a considerable portion of it) which they will occupy is, and has for many years been, in dispute between the Travancore Circar, and, I believe, the Guntapanaikenoor Zemindar, the greater part of the catchment basin of the Perryaar above the bund is (undisputed) Travancore territory. The area which will be occupied by the works and lake will be about 4,000 acres, and we shall require the privilege of felling timber and bamboos, &c., within that area, and of making roads to and from and through it.

13. The preceding remarks refer to the head works in the Perryaar tract, where the chief difficulties will be met with, but supposing them to be satisfactorily disposed of, and the Perryaar water to be flowing down the Vigay, there yet remains another point regarding which Government should be forewarned. I allude to the possibility of the proprietors of the Ramnad and Shevagunga estates objecting to the construction of new channels from the Vigay to distribute the Perryaar water; or, after allowing the construction of these channels to pass in silence, claiming the right to a certain share of water before any may be taken by the new channels. There is reason to fear that if such a claim were raised in a Court of law it would be not easy to refute it, though it would be very easy to show that the claimants got as much water as they ever did. After the Perryaar water has reached the Vigay, it will always be possible for any one interested to assert that it is Vigay water, not Perryaar water, and to object to being forestalled by a new channel above them.

14. With reference to this question, I have ascertained that the Ramnad and Shevagunga ryots have no claim, at least no instance of its having been asserted is known, to any fixed share of Vigay water. They do not claim to cut corumboos in the Madura reaches of the river, even when the river bed is gridironed with them, and when not a drop is flowing past the limits of the district to water their withering crops. In fact they receive water only when the Vigay is in fresh sufficient to wash away corumboos. But this, it will be observed, might not preclude their raising a claim against a *new* or even an enlarged channel.

15. With a view to facilitating the settlement of the question, if it ever does (as it probably will) arise, I have requested the Superintending Engineer of the District to have accurate river registers kept at the Perranny, Chittanny, and at the Vigay pavement, so that, by the time the Perryaar water is turned into the Vigay, we shall have a record of the quantities of water flowing past those points during the year. In distributing the water (after the Perryaar works are in operation), I would then arrange that the flow past the Perranny and Chittanny should be at least as much as the average of those five years, and would establish a fixed gauge register in the cutting and another above the infall into the Soroollyaar, the reading on which, taken daily and communicated by tappal to the Overseer or other person in charge of the head sluices at the Perranny and Chittanny, to be acted upon according to fixed instructions. It would be well to have another register on the Vigay, above the point where the Soroolly joins it. We should then be in a position to prove, from our recorded register, in any Court of law what proportion

of the supply at the Perranny on any day of the year or for the whole year was Perryaar water, and I would invite the Ramnad and Shevagunga Zemindars to depute one of their servants to satisfy themselves that the registers were accurately kept and correctly gauged.

16. The Ramnad and Shevagunga ryots will of course receive considerable benefit by the additional supply thrown into the Vigay; but it is nevertheless probable that the question above noticed will be raised. The difficulty would perhaps be met by allowing the Ramnad and Shevagunga Zemindars to share with Government the expense of the project, giving them a proportional share of the additional water; but in that case Government would have to interfere with its own ryots in the matter of corumboos, and there would be such complication of interests that it would be an arrangement not easy to carry out satisfactorily. There would be some saving in the cost of the project, as some of the new channels would not be required, and the others would be smaller and shorter than they otherwise would be. But looking to the complication and interference involved in such an arrangement, and to the great need of water in the Meyloor talook, I am of opinion that we should use as much of the additional Perryaar water as our ryots want, and allow any surplus to flow down the Vigay, a free gift to our neighbours below us.

17. For the sake of distinctness I have, in my report, assumed that the whole of the additional irrigation will be below the Perranny,* and, because it gives the maximum cost of the undertaking, the estimates are framed on the same hypothesis. There is little doubt, however, that the Sorooly ryots will not allow the Perryaar water to pass the heads of their channels without taking as much of it as they can use in the extension of their paddy crop. The Perryaar water used for this purpose must be distributed entirely by the flowing channels, and none of it should be stored in the Sorooly tanks. If the ryots in this part of the district could be brought into communication with the sugar exporters, three or four thousand acres of sugar-cane could be raised along the banks of the Sorooly.

* 25 miles west of Madura town, marked on Maps 5[1] and 5[2] by a red bar and letter P.

18. The results of the investigation ordered by Government are—

(1.) That the project is feasible.

(2.) That it will cost (including distribution) £ 175,000.

(3.) That it will supply, annually, water sufficient for the irrigation of 149,000† acres of paddy, in addition to the 40,000 or 45,000 acres already under irrigation by the Vigay and its tributaries.

† The aggregate area of the two crops raised during the year.

INTRODUCTION TO REPORT ON THE PERRYAAR PROJECT.

The principal division of the Madura District, consisting of the three talooks, Meyloor, Madura, and Tirumungalum, is a strip of country running north and south; its eastern boundary marching with the adjoining Zemindary estates of Shevagunga and Ramnad, and on the west separated from the Dindigul division of

the district by the mountains and jungle which extend almost continuously from Nuttom on the north to Srivilliputur on the south, where they run into the general range of the Western Ghauts, which here separate British territory from the Travancore country.

Its area, excluding uninhabited mountain and jungle, is about 1,200 square-miles, with a population of very nearly half a million.

The Vigay river, passing through the only opening in the hills, which form the western boundary, flows across the strip; the length of its course within the limits above defined being about thirty-three miles. In this length several river channels are taken off, most of them to fill tanks during the short and uncertain periods of Vigay freshes. The principal channels are the Vadakurry, the Tenkurry, the Nellayoor, and the Madacolum.

"Vada"—north.
"Kurry"—bank.
"Ten"—south.

The two first named have the advantage of anicuts across the river at their heads, the other two as well as all the other channels are supplied by means of temporary spurs (made of grass and sand—corumboos) run out into the river.

The numerous tanks supplied by the channels were many of them first class reservoirs originally, but are now so silted up as to be capable of storing not much more than half the quantity of water they were designed to hold; they occupy a great deal of valuable land, and in the attempt to get as much water as they require, the ryots of one tank frequently cause injury to their neighbours above them, by damming up their escape calingulahs and flooding land by the extended water spread.

The tanks having become shallow in proportion to the area of the water spread, there is enormous waste of valuable water by evaporation; I calculate that this waste amounts to at least thirty per cent. of the water stored.

The character of the Vigay makes the tank system essential. For some reason or other the quantity of water received into the channel of the river bears a very small proportion to the rain-fall on its catchment basin, the average annual rain-fall registered at Periacolum and Madura is 32 and 41 inches respectively. On the Cumbum valley (where no register has been kept) it is at least as much as at Periacolum, in the Wursanaad valley it is probably less; taking it at only 33 inches over the whole catchment basin above the Peranny, it would amount to 3,600 millions of cubic yards per annum, and supposing that only one-third of this found its way into the streams and rivers, so as to be available for irrigation, there would be more than enough (with due allowance for the enormous waste on tanks) for three times the extent of paddy crop now raised.

Yet it is affirmed by good authority that in an average year not a drop of Vigay water reaches the sea, but this I think is hardly sufficiently well established to be accepted as the fact. My belief is that sufficient water for more than double the present area of irrigation *does* flow down the Vigay, but that three-fourths of the annual supply passes down the river at three times the rate at which all the channels together can draw off water from it, so that if the big freshes could be detained, so as to be spread over, say sixty days, instead of running off at three times the

rate in twenty days, it would be found that there would be water enough (if the tanks could contain what it would be necessary to store) for double the present area of rice-crop.

However this may be, there is no doubt as to the main fact, that the supply of water obtained from the Vigay is so precarious and scanty that even in good years the paddy crop barely covers 22,000 acres annually, although the existing channels and tanks command land enough, and have sufficient hydraulic capacity, for the irrigation of fully double that extent of crop if only a sufficient supply of water delivered at a regular moderate rate be ensured.

This Vigay irrigation is situated in the Madura talook, the middle one of the three named above. In the Meyloor talook there is but one river, and that but a small stream, at its northern extremity, under which a small extent of land receives a good and certain supply. All the rest of this talook is dependent for irrigation on the local surface drainage, stored in small shallow tanks, the majority of them being mere ponds. Situated, as all the land of this talook is, within a few miles of the watershed, there are no well-defined streams; the Allighiry hills form a dyke, turning all the hill streams to the north and south round the flanks of the talook.

The north-east monsoon, from which this talook receives what rain it *does* get, is very uncertain so far south and inland, and the mountains to the west of it (the streams from which, as above shown, do not flow through this talook) no doubt draw away from it a considerable proportion of the rain cloud which may have travelled so far.

Under these circumstances, it is not surprising that agricultural operations are but seldom rewarded by a good crop. If the ryot is so fortunate as not to find the ground as hard as brick at the ploughing season, the chances are that rain necessary to bring the crop to maturity will not fall at the expected time.

And the cultivation of wet crops is hardly a less precarious business, failure being attended with greater loss, and success attained generally at much expense of labor and money on raising water from wells and pools.

Almost every alternate season is one of scarcity in this talook, and when an exceptionally dry year occurs, there is severe distress, and the population is thinned by death and emigration. In 1861-62 and again last year it suffered severely in this way.

If the water supply in the Vigay were sufficient, half of Meyloor could be irrigated from it.

Years before the country came into our possession, the Native rulers appear to have recognized the need of a better supply of water for the Madura District: several not very skilfully devised attempts were made to turn streams flowing on the hill table land west and south of the Cumbum valley through the water-shed separating them from the Madura rivers. (See reports by Captain Faber in 1837, by Captain Horsley in 1846, by Captain Scott in 1856, and by myself in 1859 and 61.) In 1837 Captain Faber proposed the diversion of a small stream (the Chinna Moollyaur) from the mountains at the southern corner of the Sorooly valley, which though comparatively but a small measure of relief, would have been beneficial

and remunerative. It was taken in hand in 1838, but given up in consequence of the workmen asking higher wages than was anticipated.

The streams which these projects were to turn into the Madura District are tributaries to the Perryaar, the river which I propose to deal with.

From a Report by Mr. Hodgson, dated 28th March 1808, which has lately (17th November 1865) come to light, we learn that at that time there was in existence a tradition ("handed down from father to son, through many generations") of a scheme for the improvement of the Madura and Ramnad Districts apparently identical, as regards the stream which was to be the means of improvement, with the project which I proposed to Government in 1862, and which forms the subject of the following report; but this tradition appears to have been extinguished by the unfavorable report of the late Sir J. L. (then Captain) Caldwell notwithstanding the very slight basis on which that report was founded.

REPORT ON THE PERRYAAR PROJECT.

1. The Perryaar has its sources on the northern slopes of a mountain range—6,000 feet above the sea—about fifty miles north-east of Palamcottah in N. Lat. 9°10′, whence it flows from south to north till it reaches N. Lat. 9°31′ where it turns due west.

2. At the angle formed by this change of direction it receives the united streams of the Perrya and Chinna Moollyaar, which bring to it the drainage from the mountains and forests to the west and south. Here the Perryaar is only four miles distant from the southernmost sources of the Sorooliyaar. And its bed only 170 feet below the water-shed ridge from which those sources flow. This, therefore, is the point where I propose to turn its stream into the Madura rivers.

3. The required works will be—

(1.) A bund to close the valley by which at present it takes its course to the westward.

(2.) A cut through the water-shed, which separates that valley from the head-waters of the Sorooliy.

4. The first points to be settled are the exact site of the dam and the level at which the water is to be taken.

Site for the Bund.
See Drawings Nos. 1 and 2.

5. The site which I have fixed upon as the best is immediately above the second bend, 800 yards below the *debouchure* of the Moollyaar. This site will give us the advantage of a saddle where the escape can be established, detached from the bund. Here too the bund will be shorter and take a smaller quantity of material than at any other site immediately below the Moollyaar junction.

Rocky bed of river a disadvantage.

6. The soil here as elsewhere on these hills is good, an argillaceous loam, varying in depth from a few inches to many feet; below it is the rock, gneiss and sienite. This rocky substratum, exposed as it is in the river bed, is a serious disadvantage, as it will facilitate percolation beneath the bund, and that too just where the water pressure will be the greatest.

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Bund to be of earth, not of masonry.

7. I have decided against a masonry bund for the following reasons:—

(1.) Its enormous cost, more than three times that of an earthen bund.

(2.) The uncertainty of our being able in anything like a reasonable time to execute such a work (requiring a very large number of skilled workmen) in such an out-of-the-way part of the country, and where every parah of lime would have to be brought 25 miles.

(3.) Moreover, a masonry bund, even though founded on rock, has its disadvantages; especially when, as in our case, the depth of water to be held up is very great; and the necessary* provision for emptying the lake, a source of weakness and danger, which an earthen bund would not be exposed to.

* Necessary in the case of a masonry bund for the inspections and repairs which would certainly be required.

8. The serious risk of percolation between the rock and its base is the sole objection to an earthen bund. The soil being so good it will in all other respects be better than one of masonry, stronger, less permeable in its mass, and far more likely to endure for ages.

The risk of percolation met.

9. By the following method I believe the danger of percolation above alluded to will be removed. The execution of the works will occupy four or five working seasons. In the first season I propose to throw a loose stone dam across the bed of the river, which will raise the water surface 20 to 60 feet, according to the state of the river. The earthen bund will be constructed in front of this stone dam, as shown in sketch No. 6, and the stone dam will be ultimately raised to the 120 feet level, and form a rear retaining wall to the bund. In the still water in front (of the work in progress) the silt brought down by the river will be deposited. I expect that the accumulated deposit of three seasons will be at least 30 feet thick, with a long slope extending a mile and a half up the river's bed. In this silt the toe of the front slope of the bund will rest, and subsequently additional layers will be superposited whenever a fresh big enough to top the escape occurs.

See Section on A B C, sheet No. 4.

10. The plan and sections on sheet No. 4, with the particulars of dimensions on the same sheet, give a better notion of the proposed bund than any written description could convey. It will be observed that I have not adopted the English practice of splitting the bund into two parts by a central vertical puddle-wall, that practice is, in my opinion, bad. It is evident that, if the puddle-wall is required at all, the earth in front of it will at the best be fluid mud, so that the effective bund to resist the water pressure is reduced to the puddle-wall and the earth in rear of it, *i. e.*, to a bund of half the mass with a front slope of about ½ to 1. If the earth in front does not become semi-fluid mud, or is not permeable to water, no puddle is required at all. The proper place for the puddle is as a lining to the front slope.

The proper level for the surface of lake.

11. After much consideration I have fixed upon 133 feet above the B. M.* on rock at Moollyaar junction as the proper normal level for the surface of the lake. It might be anything between 0 and 180 feet above that *datum*, but

* Captain Ryves' bench mark N.—Rock in Perrya Mullyaar 40 yards from junction with Perryaar.

practically the limits are 105 feet and 155 feet. The following tabular abstract of estimates of the works adapted to these two extremes, and to the four cases at 10 feet intervals between them, give a comparison of the quantity of work in each, its cost, and the time it will take to execute (the latter of course supposing the supply of labor to be the same for each).

Comparison of work and its cost for different levels of lake surface.

Level at which the water is taken.	Bund. 1,000 Cubic yards of Earth.	Bund. 1,000 Cubic yards of Stone.	Bund. Lacs of Rupees.	Escape. 1,000 Cubic feet of masonry.	Escape. Lacs of Rupees.	Cutting. 1,000 Cubic yards of Rock.	Cutting. Lacs of Rupees.	Total. Lacs of Rupees.	Total. Number of seasons' work.
105	813	200	3·6	33	·37	1,012	14·20	18·17	14
115	1,020	205	4·5	100	·67	702	9·83	15·00	10
125	1,260	210	5·6	245	1·22	431	6·05	12·87	7
135	1,480	220	6·4	390	1·80	215	3·10	11·40	4
145	2,020	235	10·5	...	·75	89	1·26	12·51	5
155	2,530	250	13·0	...	·25	30	·51	13·76	6

The *two* extremes have in their favor that no artificial drop wall would be required for the escape, a little scarping and blasting of a rocky saddle being all that would be required for that essential adjunct; the minimum extreme has, besides, the advantage of less water pressure to deal with, but the rock cutting* through the water-shed would be very heavy, and consequently, in respect to cost, and to the time it would take to carry out, this (and in a less degree the 115 feet level) must take a very low place in the order of selection. I reject the 145 and 155 feet levels on account of the greater water pressure and the extra length of bund (across saddle†) necessary, disadvantages which are not counterbalanced by the advantages of a natural escape.‡ There remain the 125 and 135 feet levels, either of which is, in my opinion, better than any of the other four in the table. I have adopted the 133 feet level as the *datum* for my designs and estimates, because at that level the quantity of rock to be blasted for the cutting will about supply the quantity of stone required for the dam, economizing thereby time and money.

* 3 miles long.
75 feet deep at the deepest.
35 ,, average depth.

† E on sketch No. 2, and ,, 3.

‡ at F on ,,

As compared with the 125 feet level—time saved $2\frac{1}{2}$ years, money saved $1\frac{1}{4}$ lacs Rupees + the value of five crops of paddy.

12. Having thus decided on the normal level of lake surface, I proceed to fix the dimensions and relative levels of the cut and escape. I take the following to be the proper conditions to be fulfilled by these works:—

(1.) At the normal water level the cut to discharge the average (exclusive of big freshes) stream of the Perryaar, during the eight months, May to December including.

(2.) No water to run to waste over the escape until the inflow exceeds an ordinary big fresh.

(3.) In extraordinary floods the lake surface, when at the highest, to be 12 feet below the top of the bund.

The length available for the escape is about 600 feet (without blasting away the opposite hill) across the saddle (E) west of the north end of the bund: the normal water level is to be 133 feet, and I estimate that the area of the lake surface will be 3¾ square-miles at the 133 feet level, increasing to five square-miles at the 150 feet level. Taking these *data*, I find that the following will satisfy the above conditions.

Dimensions and levels of the cutting escape and feet.

Escape crest to be at the 142½ feet level.
Cutting sole ,, ,, 125 ,,
Width of cutting with sides sloping 1 to 6, 40 feet.
Top of bund at the 162½ feet level.

The Escape.

13. The escape will consist of three drop walls of masonry built across the saddle west of the N. W. end of the bund, the crest of the second being 12½ feet below that of the front wall, and of the rear wall 14 feet lower than that of the second (see sheet No. 4). The flank of the bund adjoining the escape will be sustained and guarded by a wing-wall 300 feet long and from 16½ to 6 feet high, the opposite end of the escape will abut upon the rocky hill forming the west side of the saddle. The height of the front wall will be 38 feet at the lowest point of the saddle, and diminish to nothing at either side, its thickness at top will be 9 feet, and at its base (where it is highest) 20 feet, the thickness at base varying from 9½ to 20 feet. The foundation will be laid in a trench cut out of the rock. To keep the two basins full, a 3-inch pipe will be carried over the front wall from the 120 feet level in front to the same level in rear; and as an additional security there will be a tamboghy a couple of feet lower than the crest, at each end of the wall. The maximum discharge by the escape will not exceed 6¾ millions of cubic yards per hour, which would pass over the crest of the front wall with a velocity of a little more than 12½ feet per second, over the second and third walls the velocity would be respectively 14 and 14¾ feet per second, these velocities are not greater than what we have already successfully dealt with. After passing over the rear wall the flood water will flow by a natural gully back into the Perryaar, which it will fall into at about 300 yards distance from the foot of the rear slope of the bund.

Extraordinary floods.

Volume of water in inches of depth over the whole catchment basin.

In 3 days	18 inches.	
,, 2 ,,	13½	,,
,, 1 ,,	8	,,
,, ½ ,,	4½	,,

14. The possibility of an extraordinary flood of the magnitude indicated in the margin is anticipated, and the top of the bund fixed at 12 feet above the level to which the surface of the lake would, according to my calculations, be raised by such a flood.

In 3 days	30 inches.	
,, 2 ,,	22½	,,
,, 1 ,,	13½	,,
,, ½ ,,	7½	,,

15. Applying as a crucial test the (impossible) second case stated in the margin, it will be found that even then the lake surface would not rise to within 9 feet of the top of the bund, as fixed in the preceding paragraph. The relative levels fixed for the top of bund; crest of

escape; and sole of cut; and the waterways of the two latter may, therefore, be accepted as perfectly safe.

Sooroolly floods.

16. But in the case of the extraordinary flood which (in paragraph 14) I have stated is possible, and, therefore, to be anticipated and provided for; the rate of discharge through the cut would rise to 1, $1\frac{1}{2}$, or even for an hour or two at the top of the flood, to $1\frac{3}{4}$ million cubic yards per hour, which added to the Sooroollyaar's own natural flood discharge would cause very injurious inundations on the paddy lands skirting that stream.

Regulating Reservoir.

17. To prevent this I propose to construct a reservoir in the jungle tract between the foot of the hills and the Vyravenaar, in which the excess above the safe rate of discharge would be retained till the flood had passed off. I do not propose for this purpose a head sluice across the cut through the water-shed, because, as it would not do to trust to its being properly worked by hand in such an out-of-the-way place, it would have to be made self-acting and be liable to get out of order, especially as it would be exposed to the curiosity of the elephants which frequent these mountains. Besides being free from this objection, the reservoir plan has this in its favor, that it would store for subsequent use the excess water, which by the head sluice plan would be discharged over the escape back into the Perryaar below the dam. And against it, the defect of all river-fed tanks, that it will be ultimately choked with silt; but long before this occurs, we shall be able to afford to replace it by a new one, which would probably be formed by an upper bund across the Perryaar itself above the main lake. It should be remembered that the effect of a head sluice would be to raise the flood level of the lake, to meet which it would of course be necessary to make the bund a little higher and the escape drop walls a little stronger, the cost of which, *plus* the cost of the head sluice itself, would be very nearly as much as the cost of the regulating reservoir.

Effect of the addition to Sooroollyaar floods.

See the small general map on Sheet No. 5.

18. The rate of delivery of Perryaar water into the Sooroolly stream should not exceed $\frac{3}{4}$ million cubic yards per hour. This hourly addition to the natural great flood of the Sooroolly would raise the water surface about two feet at Oottampollium to $1\frac{1}{2}$ feet at Veerapaandy. The effect on the Vigay would be considerably less, I calculate that at the Perranny the flood level would not be raised more than five inches by the extra $\frac{3}{4}$ million per hour.

Capacity of the regulating Reservoir.

19. Taking $\frac{3}{4}$ million per hour as the maximum limit not to be exceeded, even in very extraordinary floods of the Perryaar, such as would occur only once in many years, it appears (see table C) that in the case of such a flood as that described in paragraph 13, the excess above that limit to the hourly rate of discharge would amount to about 35 millions of cubic yards, the Reservoir will, therefore, be made sufficiently capacious to hold that quantity of water. The works to restrict the maximum rate of delivery within the above limit, would also in a less degree regulate the rate of delivery of the ordinary big freshes. With a view to husbanding the supply of water, means will be provided for turning the whole of

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the Perryaar water into the Reservoir, when the Vigay and Sorоolly are in flood, and the Perryaar is discharging at not more than the ordinary by fresh rate.

20. The water thus delivered into the Soroolly will flow with that stream to the Vigay, but on its way will pass over several old anicuts which require repair and some improvements and alterations; for these and for embankments, and other minor works connected with the Soroollyaar, I have entered in the estimates a lump sum which I have no doubt will be ample for the work.

21. The works above described will bring the Perryaar water to the heads of the Madura channels at the Perranny and Chittanny, where the distribution for irrigation will commence.

22. Before entering upon this branch of the subject, it is necessary to calculate as accurately as possible the quantity of water we shall have to distribute, on which will depend the dimensions, length, and general direction of the channels.

The Perryaar Catchment Basin.

23. Of course there is no record of rain-fall on the catchment basin of the Perryaar above the point where I propose to take its stream. This catchment basin consists of a net work of mountain ridges divided by ravines, which open out here and there into basins and valleys, and from which issue the numerous tributaries of the Perryaar, many of them considerable streams. The lowest valley is 2,700 feet above sea level, the highest ridge 6,000 feet. The area drained is about 250 square-miles in extent, more than one-third of this is clothed with dense forest and cane jungle, and the gigantic elephant grass covers very nearly all the rest.

Rain-fall.

24. It receives the rains of both monsoons, but its principal supply is from the south-west monsoon. There being no record of rain-fall on the basin itself, I have examined the registers of rain-fall at the nearest stations of the adjacent districts, Tinnevelly, Travancore, Cochin, and Madura, and have arrived at the conclusion that in an average year the rain-fall on our Perryaar basin would be at least 79 inches, of which 47 would be received from the south-west, and 23 from the north-east monsoon, and nine by casual showers and storms during the dry weather.

25. The proportion of the rain-fall that drains off the land into the river is certainly much above the average of the South of India.

(1.) The area drained is small.
(2.) One-third of it is sheltered from the sun by dense forest.
(3.) During five or six months of the year, cloud and mist obscure the sun for at least two-thirds of the time it is above the horizon.
(4.) The ridge and ravine character of the country.
(5.) The surface drained is rock covered by a thin stratum of soil.
(6.) Beds of tributaries and of the Perryaar all rock.

Proportion of the rain-fall received by the river.

26. In my estimate of water supply, I assume that the river will receive 75 to 60 per cent. of what falls during the south-west monsoon, 60 per cent. of the north-east monsoon rain-fall, and from 53 to $37\frac{1}{2}$ of the dry weather showers, altogether 1,133 millions cubic yards in an average year.

Deduction for waste and net supply at the heads of the Madura channels.

27. The waste by evaporation before the water reaches the Madura irrigation channels will be about 48 millions cubic yards, or rather more than $4\frac{1}{2}$ per cent. on the gross annual supply. And for the waste which will occur in first filling the bed of the Vigay at the end of each dry season, I allow 18 millions, making the total deduction for waste 66 millions of cubic yards, and leaving 1,067 millions for the channels to receive, of which 593 millions will be delivered during the south-west monsoon, or 1st crop season, and 430 millions during the 2nd crop season; 44 millions being received in February and March would not come into use for paddy irrigation, but would be valuable for Sugar-cane or garden cultivation.

28. The amount of rain-fall assumed in the above, being deduced from the averages of quantities registered during a long series of years, does not include the surplus water of extraordinary floods (see paragraphs 12 and 13) which will pass over the escape and back into the Perryaar below the dam. No deduction, therefore, has been made on this account.

29. The following table exhibits my estimates of water supply for each month of an average year. I should note here that the result obtained by the method which I laid down for myself is, in my opinion, much below the truth. I believe the average annual rain-fall to be nearer 100 than 79 inches. I have, however, accepted the results as being on the safe side for our purpose :—

Table of estimated water supply.

	Rain.	Millions cubic yards received by Lake.	Loss by Evaporation. On Lake. Mns. Square yards exposed.	Loss by Evaporation. On Lake. Rate per month.	Loss by Evaporation. In transitu. Mns. Square yards exposed.	Loss by Evaporation. In transitu. Rate per month.	Total Loss Mns. cubic yards.	Millions cubic yards delivered at Peranny	Quantity for each crop.
	Inches.			Yards.		Yards.			
April ...	4·53	48	11	·30	5	·37	5·15	38	593 Mns. cubic yards for the 1st or south-west monsoon crop.
May ...	9·82	120	$11\frac{1}{2}$	·25	$6\frac{3}{4}$	·40	5·58	112	
June ...	11·94	165	$11\frac{3}{4}$	·15	9	·30	4·46	160	
July ...	11·21	170	$11\frac{3}{4}$	·10	9	·20	2·98	167	
August ...	8·12	120	$11\frac{1}{2}$	·15	$6\frac{3}{4}$	·25	3·31	116	
September ...	6·03	80	$11\frac{3}{8}$	·20	$5\frac{5}{8}$	·30	3·96	75	430 Mns. cubic yards for the 2nd or north-east monsoon crop.
October ...	11·56	165	$11\frac{3}{4}$	·15	9	·25	4·01	160	
November ...	8·46	125	$11\frac{1}{2}$	·15	$6\frac{3}{4}$	·20	3·07	120	
December ...	3·03	50	11	·17	5	·25	3·12	45	
January ...	1·52	35	$10\frac{7}{8}$	·20	$4\frac{1}{2}$	·30	3·52	30	
February ...	0·96	25	$10\frac{7}{8}$	·25	4	·33	4·01	20	44 Mns. cubic yards.
March ...	1·80	30	$10\frac{7}{8}$	·30	$4\frac{1}{4}$	·35	4·75	24	
Annually ...	78·98	1,133	......	......	...	......	47·95	1067	

30. We have now to determine how much land this additional water supply will irrigate, and where this land is to be sought.

31. In an average Madura tank of the first and second classes, the waste by evaporation is about 35 per cent. during the south-west monsoon, and fully 25 per cent. during the north-east monsoon of the quantity stored. It will, therefore, be advisable to irrigate, direct from the river channels, as much land as we can ensure a constant stream for; for this direct irrigation each acre of the 1st crop will require 6,250 cubic yards of water, and for the 2nd or north-east monsoon, crop, 4,500 cubic yards. For the land to be irrigated from tanks, 9,000 and 6,666 cubic yards would have to be stored for each acre of 1st and 2nd crop, respectively. Land receiving irrigation partly direct from the channels and partly by water stored in tanks would require per acre about the means of the above quantities, a large proportion of the land should be irrigated in this way.

Quantity of water per acre for one crop of Paddy.

32. The following is the way I would dispose of the water. I will assume that for the south-west monsoon, or *first* crop, the seed beds are sown in the end of April and beginning of May, the paddy planted out early in June, and the crop reaped in September, and that it would require per acre to be watered as follows:—

30 days,	80 cubic	yards per diem on $\frac{1}{16}$th of the area	...	150 cubic yards.
10 "	75	" " on the whole	... ...	750 "
15 "	60	" " "	... ...	900 "
30 "	50	" " "	... ...	1,500 "
15 "	60	" " "	... ...	900 "
25 "	70	" " "	... ...	1,750 "
		Total for the 125 days	...	6,250 "

	Millions cubic yards delivered at Perranny.
May	112
June	160
July	167
August...	116

Comparing this estimate of requirements with the table of water supply (paragraph 29 ext. in margin), it appears that in August, when the supply is least, the demand will be greatest, by suiting the area to be irrigated direct from the channels, to the supply of this month, we shall therefore arrive at a safe result. The *average* daily delivery in August will be 3·74 millions cubic yards; and bearing in mind the regulating effect of the reservoir described in paragraphs 16 and 18 of the Perryaar lake itself, the *minimum* daily supply may be safely assumed to be at least half the average, or 1·87 millions cubic yards, which is enough for 26,700* acres of direct irrigation at the August rate; for the same reason the mean daily delivery will be very nearly the same as the average, *i.e.*, it will be as many days at and *above*, as it will be *below* that quantity, the area of land to receive half its irrigation direct from the channels will, therefore, be also 26,700 acres.

* 1·87 mns. = daily supply.
—— acres daily requirement.
70 =

1st Crop by Perryaar water.

33. The south-west monsoon supply of water will thus be disposed of as follows:—

164 millions cubic yards in direct irrigation of 26,714 acres.						
204	do.	do.	{half direct / half tank}	do.	26,714	do.
222	do.	do.	Tank	do.	24,666	do.
593	do.		giving a total 1st crop, or		78,094	

Second crop by Perryaar water.

34. By a similar method, with proper allowance for the difference of season, I find that the north-east monsoon crop would be made up of—

9,000 acres of direct irrigation using			40 Mns. cubic yards		
22,500	do.	{half direct / half tank}	do.	126 do.	do.
39,600	do.	Tank	do.	264 do.	do.
71,100	do. irrigated by the			430 do.	do.

Total annual addition to rice crop.

35. Making a total addition of 149,000 acres to the annual rice crop, for which, allowing one-fourth for fallow, 100,000 acres of land will be required, 78,000 to be cultivated during the south-west monsoon season (May to September), and 71,000 in the north-east monsoon (October to January).

36. Part of this additional rice crop will receive its irrigation from existing channels and tanks, now supplied by the Vigay, and which will be used to distribute also Perryaar water; but a large proportion of the 100,000 acres will have to be sought for in land hitherto beyond the reach of the river channels.

The land for the additional cultivation to be taken in the Meyloor talook.

37. Land of fair quality and of sufficient extent lying at suitable levels can be found in the Meyloor and Tirumungalum talooks, north and south of the tract already partially irrigated by the Vigay. I propose to give the Meyloor talook the preference; because *there* an artificial supply of water is more needed than in the Tirumungalum talook, which has comparatively a very fair natural supply by the Goondaar and Sheveraycotta streams. I propose, however, to provide for throwing into the Tirumungalum rivers the surplus water of big freshes to fill the tanks on that side when required.

Distribution of Perryaar water by old Vigay channels.

38. I will first explain how the Perryaar water, and how much of the supply will be distributed by the existing river channels and tanks dependent on them.

On the south of the river.

39. On the south bank of the river, the tract which is within the influence of these old channels, is bounded on the south and west by the Tenkurry and Nellayoor channels, the trunk road, and the Goondaar river. It contains 61,000 acres, of which fully 40,000 are fit for paddy cultivation; of the latter (arable area) about one-half is generally under crop in a fair season, 13,000 acres being irrigated, the remainder dry, the extent of irrigation during the south-west monsoon is under 4,000 acres. I therefore propose to allot to this tract Perryaar water, sufficient for the irrigation of 36,000 * of first crop and of 27,000 † acres of second crop.

* (40,000—4,000.)

† (40,000—13,000.)

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South of Vigay.

40. By enlarging the Tenkurry channel (which draws its supply from above the Chittunny, the lower of the two Vigay anicuts,) and connecting it with the Nellayoor and Madacolum channels, which will require no enlargement, the Perryaar water for this tract will be economically conveyed to the several points from which the channels of distribution will draw their supply; of the latter many new ones, with proper sluices and other small masonry works, will have to be constructed, and the principal tanks will have to be repaired and improved. The cost of the works for this tract will be under a lac of Rupees.

Direction of Perryaar water by old channels on north bank.

41. On the north bank of the Vigay the breadth of land commanded by the existing river channels is considerably less than on the other side of the river, not more than 25,000 acres, of which about 14,000 are available for cultivation; of this culturable area, about 6,500 acres are irrigated in the north-east monsoon, and barely 2,000 in the south-west. The old channels on this side will, therefore, be adapted by means of extensions, and new branches to the distribution of Perryaur water for 12,000 acres of first and 7,500 acres of second crop. The cost of this adaptation will be about 24,000 Rs.

42. Without a radical reform of the system of management of irrigation, both on the north and south banks, the works proposed will be ineffective. It is my opinion that it will be essential that the charge of the works and the control of the distribution of water be vested solely in the Engineer Department, as in the Godavery and Kistna deltas.

Area of additional irrigation beyond the reach of the old Vigay channel.

43. After allotting, as above, as much water as can be distributed by them, to the existing channels, there will still remain Perryaar water enough for the irrigation of 30,000 acres of first and 36,500 of second crop, the land for which will have to be found outside the tract, to which irrigation from the Vigay has hitherto been restricted. Of this additional area, I propose to allot 25,000 and 30,000 acres of first and second crop, respectively, to the Meyloor talook, the remainder to be taken up in the extension of the Nunjah cultivation under tanks in the Tirumungalum talook.

New channel for Meyloor talook.

44. To convey the Perryaar water into the Meyloor talook, an entirely new channel, with proper branches, will have to be constructed. This channel will draw its supply from above the Peranny anicut by the same head as the old Vadakurry channel, which will have to be enlarged to enable it to convey the additional volume of water for $2\frac{1}{4}$ miles. Here the separation of the shares for the old Vadakurry and Sholavundaun irrigation and of the new Meyloor channel will be regulated by a simple masonry structure, and the share of the latter will be conveyed from that point by the new channel (following the line marked by green on the Map No. 5.) into the heart of the Meyloor talook.

45. As it will be carried across the drainage from the southern slopes of the Sirumullays and Aligherry hills, this channel will be an expensive work; including its branches and subsidiary works, it will cost $2\frac{3}{8}$ lacs of Rupees.

Arable area in the tract embraced by the new channel.

46. The whole of the tract bounded on the north by this green line and by the Vigay on the south will be commanded by this channel; its area is 158,000 acres, of which 25,000 have been already disposed of in paragraph 40. Of the remaining 133,000 acres, it appears from a Statement furnished by the Collector that not more than 36,000 acres are cultivated, 16,000 being irrigated, the remainder dry, the ayacut, *i.e.*, assessed arable area, is about double the area of cultivation, say 70,000 acres, 63,000 being set down as occupied by tanks, topes, villages, roads, &c., or as unfit for cultivation.

Land available for the additional paddy crop.

47. These figures, though no doubt not perfectly accurate, as the Revenue Survey has not yet reached the Madura District, are sufficient to show that the unirrigated arable area in the tract commanded by the proposed new channel is, during the south-west monsoon, more than double the area of land required for the Perryaar first crop, and during the north-east monsoon, about one and three-quarter times the proposed area of second crop, and that of the former about 24,000, and of the latter about 13,000 is land already assessed as Nunjah,* there is therefore no doubt about sufficient land fit for paddy cultivation being found in the tract specified for the *first* crop, the question is whether in the 40,000 acres of arable Punjah land (30—13) 17,000 acres fit for Nunjah, if only water be supplied, will be found for the second crop. From what I know of the country and the soil, I think this question may safely be answered in the affirmative.

* But for which no water is supplied.

48. However, before the channel is completed, the Revenue Department will no doubt be able to decide this point, and any deficiency of Nunjah land could be made good, either by extending the channel a few miles further north, or by embracing a greater breadth (by a branch from the 22nd mile running north of the Nursingapatam hills to Arasaputty and Tombaputty,) or by slightly reducing the share of water allotted to this channel, and giving the difference either to Tirumungalum or to the Soroolly ryots.

Water to the Tirumungalum talook.

49. The water for the extension (additional first crop 5,000, second 6,500) of the Nunjah cultivation under tanks and Goondaar channels in the Tirumungalum talook, will be taken from the Tenkurry main duct by a channel through the Vikramungalum gorge, whence it will be distributed by natural drainages, requiring only slight excavation and embanking here and there.

The work of which the project will be compared, and their cost.

50. The complete project will then be made up of the following works and groups of works, the cost of which according to my estimates will be as set opposite each below :—

		Lacs of Rupees.
1.	Preliminary (ghaut, roads, buildings.) ...	0·11½
2.	The Perryaar bund and its escape ...	8·67
3.	Cutting through the water-shed	3·12

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4. Regulating reservoir and other works between the cutting and in-fall into the Soroollyaar ... ... Lacs of Rupees. 0·75
5. Works on the Soroollyaar ... ... 0·80
6. Distribution of water... ... ... 4·03
The total estimated cost being .. ... 17·49

To this estimated cost, I propose to add a reserve fund of 20 per cent. to be at the disposal of Government to meet deficiencies, if any occur, in my estimates, or to carry out extensions or additions which may * be found desirable or necessary. The sum to be allotted for the project would then be 21 lacs or £210,000.

* If the supply of water turns out to be much more than I have estimated at, the new distribution channel will have to be made bigger and longer.

Annual value of the water supplied.

51. The water-rate on 149,000 acres of rice crop at four Rupees per acre would be six lacs, all but 4,000 Rupees; and supposing that 26,000 acres of dry cultivation be given up, the net increase of land revenue would be about $5\frac{1}{2}$ lacs of Rupees. For management and repairs I would allow as much as 50,000 Rupees per annum, leaving five lacs as the net profit on the capital expended, which is $28\frac{1}{2}$ per cent. on the estimated cost, or $23\frac{3}{4}$ per cent. on the 21 lacs which I propose should be assigned for the project.

Allowance for repair and maintenance.

52. The allowance for management and repair will appear high when compared with the Budget grants for that purpose in this Presidency which are, however, notoriously inadequate. The following is a comparison between what is allowed for the Godavery delta works and the proposed allowance :—

	Per million cubic yards of water delivered.	Per acre of the tract commanded by the channels.	Per acre irrigated first crop only.	Per cent. on gross annual profits.
	RS.	AS.	AS.	
Godavery	45	3	7	8
Perryaar	49	$4\frac{2}{3}$	10	9

with due allowance for engineering advantages or disadvantages, the figures in the first and second columns, giving the rates for management and repairs per unit of area over which the channels have to be taken, and per unit of volume of water delivered, are to be taken for comparison.

53. The relative advantages and disadvantages with respect to the cost of maintenance and management of the Godavery delta works and the works proposed for Madura, are about as follow :—

(1.) The Godavery head works are exposed to far greater wear and tear, than will be those of the Perryaar project.

(2.) The cross drainage per acre of area commanded by the channels is as five in the Godavery to three in the Perryaar case.

(3.) In consequence of the greater hydraulic slope of the Madura channels, erosion by current will be greater than in the Godavery channels.

(4.) This greater fall will, on the other hand, give them the advantage in size, number, and aggregate length of channels, which will be considerably less *per unit of area* than is the case in the Godavery delta.

(5.) The numerous tanks required for the Madura irrigation, and which per acre of irrigation cost considerably more to keep in repair than channels for direct irrigation, is a disadvantage.

(6.) The Godavery maintenance has the advantage of water-carriage for its material, and of a slightly lower rate of wages.

(7.) The expensive river works, annually required to keep a deltaic river in its course (the Godavery divides into three such rivers, aggregating 150 miles in length within the △ below the anicut besides 25 miles above), is an extra and very heavy charge, from which the maintenance of the Madura works will be free.

(8.) In the Godavery the irrigation is charged with the maintenance of the locks (thirty-five in number).

54. A careful consideration of the above shows that the charge for maintenance and repair of the proposed Madura works, should be rather less (rateably for area and volume of water delivered) than the *proper* charge, (after deducting the extra charges for river works and repair of locks) for the same purpose in the Godavery delta. But the annual grants for the repair and maintenance of the Godavery works have during the last few years, been so inadequate, that unless in future they are very largely augmented, the works will get seriously deteriorated in value and usefulness. The Godavery experience can, therefore, be only used as a warning and as giving us a minimum rate (for works of this same kind with similar conditions) which the charge for maintenance, &c., should not be allowed to fall to. I therefore assume that the annual charge for repair and maintenance of the Perryaar irrigation works will be, as stated in paragraph 49, 50,000 Rupees.

55. Of course, the anticipated increase of revenue will not take place immediately after the completion of the works, considering the large extent of ayacut Nunjah, for which at present there is no water, I think that one-fourth of the full profits, or seven per cent., may be expected in the second year, rising to fifteen per cent. in perhaps six or eight years, and subsequently gradually rising to the full amount.

Ability of the ryots in the Madura and Meyloor talooks to bring under cultivation the additional area of paddy, and to pay the estimated increase of land revenue.

56. There need be no doubt about the ability of the ryots to bring under cultivation the additional area, and to pay the additional revenue; the following remarks on this point may be useful. The area which will be under the command of the channels is about 375 square-miles; this may be conveniently taken in two blocks: one, which will be the richest, being the tract already partially irrigated by river-channels and tanks, the other, the outside tract noticed in paragraphs 37 and 43. The first contains about 135 square-miles, in which the annual extent of rice *crop* will be raised from about 24,000 acres to 80,000, and the land revenue from 1·45 lacs to 4·75 lacs of Rupees;

the second has an area of 240 square-miles, and the proposed works will, it is expected, raise the area of paddy cultivation from 27 to 69,000 acres of *crop*, and the land revenue, from $1\frac{2}{3}$ to $3\frac{3}{4}$ lacs. In the richer tract the land revenue will then be at the rate of about 3,500 Rupees per square-mile,* by no means an unprecedented rate for blocks of similar extent. In the Cauvery delta† there are blocks of similar and even considerably greater extent, where the rate per square-mile is as much as 4,000 Rupees.

Taking the whole of the habitable‡ country of the three talooks, Tirumungalum, Madura, and Meyloor, the population is about 400 per square-mile; the population of the 375 miles in the richest and most densely peopled part of the district may, I think, be fairly assumed to be at the rate of 450 per square-mile, or 170,000 people, and supposing the full increase of revenue take place so soon as fifteen years hence, and the population to have increased by only 30,000 in that period, the rate per head would be $4\frac{1}{4}$ Rupees.§ The land revenue‖ collected last year in the Godavery delta was at the rate of 5 Rupees per head of its population. From the above it appears that the amount to which it is expected that the Perryaar works will raise the land revenue in Madura proper, whether considered with reference to extent of country or population will not be more than experience shows may be expected.

(Signed) J. G. RYVES, Captain, R. E.,
Supg. Engr. on Special Duty.

CHINNAMANOOR,
7th August 1867.

* Every square-mile within the ring fence the block includes town, topes, dry and wet, uncultivable waste, roads, &c., &c.

† For instance, the tract between the Peruvelly and Wyacondam in the Trichinopoly talook.

‡

		Sq. M.
Total area	... ...	1,597
Uninhabited mountain and jungles...		397
		1,200
	Population...	486,000

§ Land Revenue ... $8\frac{1}{2}$ lacs Rupees.
Population 200,000

‖ For the year 1865-66.

Land Revenue ... 35 lacs Rupees.
Population ... 700,000

	Rate.	Amount.	Total.	Total of each work or group of works.
	RS.	RS.	RS.	RS.
1.—Ghaut, 25 feet wide, gradient 1 in 20.				
8,000 Running yard, excavation and formation at $1\frac{1}{4}$ Rupees per running yard ...	$1\frac{1}{4}$	10,000		
6 small bridges at 250 Rupees each ...	250	1,500		
Metalling with broken stone	$\frac{3}{8}$	3,000		
Revetments and contingencies	......	1,500		
Improving road from Chinnamanoor to the foot of the ghaut, 18 miles at per mile ...	500	9,000		
3 small bridges across deep hill streams ...	......	6,000		
Clearing jungle and levelling tracks through the hills above the ghaut, 10 miles at 500 Rupees + 25 at 100	......	7,500		
Felling and trimming for transport valuable timber and bamboos within the water spread of the lake	......	6,000		
Carriage of do. to Chinnamanoor 1,500 bandies, 25 miles	......	4,500		
Total for ghaut, roads, and clearing jungle ..	......	....	49,000	
Deduct value of timber, 1,500 bandy loads at 25 Rupees	......	....	37,500	
				11,500
2.—Cutting through Water-shed.				
227,787 Cubic yards of Rock, 52,133 cubic yard Earth.				
6,100 Miners, months, at per mensem ...	$17\frac{1}{2}$	1,06,750		
2,000 Coolies ,, ,, ,,	12	24,000		
Total labor in Quarry...	......	....	1,30,750	
120,000 lbs. of Gun-powder	$\frac{1}{5}$	24,000		
375,000 yards of Match	$\frac{1}{80}$	4,688		
15,250 lbs. of Steel	$\frac{1}{2}$	7,625		
244,000 lbs. of Iron	$\frac{1}{8}$	30,500		
146 months' work of a forge	50	7,300		
Total Materials...	......	....	74,113	
114 Carpenters, months, at per mensem	25	2,850		
1,225 Coolies ,, ,, ,,	11	13,475		
968 Waggonmen ,, ,, ,,	15	14,530		
3,950 Bullocks ,, ,, ,,	$12\frac{1}{2}$	49,375		
Total for Transport...	......	80,220		
Of which $\frac{2}{3}$rds to be charged to bund, leaving against cutting	......	....	26,740	
Non-effective 10 per cent., of working strength on $\frac{3}{4}$ pay = $7\frac{1}{2}$ per 100 on 1,57,490 Rupees	......	11,812		
Hutting at $\frac{3}{4}$ Rupee per man × month (11,610)	......	8,708		
Maistries and share of Hospital Establishment	......	9,000		
Incidental charges at $2\frac{1}{2}$ per cent., on 2,31,603 Rupees	......	5,790		
Share of estimated cost of plant, tools, and machinery	......	45,238		
			80,548	
Total estimated cost of the cutting...	......	....	....	3,12,151

PERRYAAR PROJECT ESTIMATE.

	Rate.	Amount.	Total.	Total of each work or group of works.
	RS.	RS.	RS.	RS.
3.—The Escape.				
37,650 cubic feet of cut-stone work in large masses for crests at	$\frac{7}{10}$	26,355		
50,430 ,, dressed work in faces	$\frac{1}{2}$	25,215		
294,797½ ,, coursed rubble	$\frac{1}{3}$	98,266		
84,000 ,, excavation in rock for foundation	$\frac{1}{10}$	8,400		
			1,58,236	
Incidental charges at 5 per cent.	......	7,912		
Share of cost of plant, tools, machinery ...	......	5,852		
			13,764	
Total estimated cost of the Escape...	......	....	....	1,72,000
4.—Bund.				
1,293,018 Cubic yards Earth, 192,824 cubic yards Puddle, 4,943 cubic yards Stone Wave Screens.				
19,320 Coolies, months, at per mensem ...	10½	2,02,860		
177 Elephants ,, ,, ,,	50	8,850		
478 Carpenters ,, ,, ,,	25	11,950		
4,780 Coolies ,, ,, ,,	11	52,580		
1,260 Waggonmen ,, ,, ,,	15	18,900		
3,806 Bullocks ,, ,, ,,	13⅓	50,747		
288 Boats' crews ,, ,, ,,	80	23,040		
Total for Earth, Puddle, and building Wave Screens	......	....	3,68,927	
Stone for dam and Wave Screens, &c., 227,787 cubic yards at two-thirds of the cost of transport from cutting = $\frac{2}{3} \times 80{,}220$ ...	......	....	53,480	
Non-effective 10 per cent of working strength on ⅔rds pay = $\frac{20}{300} \times 324{,}141$	......	21,609		
Hutting at ¾ Rupees per man × month = ¾ × 27,905	......	20,929		
Maistries and Hospital Subordinate Establishment	......	24,000		
Incidental charges, including working Pumps and Syphons	......	13,300		
Share of estimated cost of Tools, plant, and machinery	......	1,93,047		
			2,72,885	
Total estimated cost of Bund...	......	....	....	6,95,292
Total for the Head Works at the Perryaar...	......	....	....	11,90,943
5.— Regulating reservior above the in-fall into the Soroollyaar	......	....	80,000	
Repairs to Anicuts across the Sooroollyaar and Embanking	......	....	75,000	
				1,55,000
6.—Distribution north of the Vigay.				
Excavation of main channels	......	74,718		
Do. of branches	......	23,200		
Total Excavation...	......	....	97,918	
Masonry for cross drainage { under Tunnels 63,850; Escapes ... 45,000 }	......	1,08,850		
Do. in Sluices	......	32,100		
Do. in Bridges	......	10,800		
Total Masonry...	......	....	1,51,750	

PERRYARR PROJECT ESTIMATE.

	Rate.	Amount.	Total.	Total of each work or group of works.
	RS.	RS.	RS.	RS.
Purchase of Land and Contingencies... ...	......	....	32,264	
Repairing Tanks	......	....	25,000	
Total Distribution north of the Vigay...	......	....	....	3,06,932
7.—Distribution south of the Vigay.				
Excavation of main channels	......	21,602		
Do. ,, branches	......	28,697	50,299	
Masonry for cross drainage to Escapes ...	......	7,500		
Do. in Sluices	......	17,430		
Do. in Bridges	......	2,500	37,430	
Purchase of Land and Contingencies... ...	......	....	8,796	
Total Distribution south of the Vigay...	......	....	....	96,525
Grand Total of Estimate...	......	....	....	17,49,400
Add 20 per cent., for a Reserve Fund...	......	....	....	2,50,600
Total to be assigned for the Project...	......	....	....	21,00,000

		RS.	RS.
Ghaut roads and clearing Jungle		11,500	
Cutting through the Water-shed...		3,12,151	
Masonry Escape		1,72,000	
Bund		6,95,292	
Total for the Head-Works at the Perryaar		....	11,90,943
Regulating reservoir and works on the Soroollyaar		....	1,55,000
Distribution	North of the Vigay.	3,06,932	4,03,457
	South of the Vigay.	96,525	
Estimated cost of the Project...		....	17,49,400
Add for Reserve Fund...		....	2,50,600
Total to be assigned for the Project...		....	21,00,000

CAMP CHINNAMANOOR,
7th August 1867.

(Signed) J. G. RYVES, Captain, R. E.,
Supg. Engr. on Special Duty.

No. 2.

Quantity in the Cutting.

Rock.

Level of Rock surface.	Length, yards.	Depth, Feet.	× Middle width / 9	× Sides. base / 9×height.
125				
	200	1½	300	450
128				
	850	7½	6,475	48,567½
137				
	500	14	7,000	98,000
141				
	50	19	950	18,050
147				
	375	29	10,875	315,375
160				
165	315	39	12,285	479,115
160				
	160	30	4,800	144,000
148				
	50	17½	875	15,312½
134				
	360	7¾	2,790	21,622½
125				
	60	1	60	60
			46,410	1,140,552

46,410 × $\frac{40}{9}$ = 206,666

1,140,552 × $\frac{1}{54}$ = 21,121

Total Rock = 227,787 C. yards.

Top Earth.

Length, yards.	Width feet.	Depth feet.	9 × C. yards.
300	20	3	18,000
1,050	25	6	157,500
550	30	6	99,000
375	50	2	37,500
315	45	4	56,700
200	40	6	48,000
500	35	3	52,500

Total Earth = 469,200 × ⅑

= 52,133⅓ C. yds.

Estimate of the Labor, Materials, and Transport for the cutting through Water-shed and Stone dam.

Season.	Quantity, cubic yards, to be done in the season.	Cubic yards per diem.	Months.	Quarry. Labor. Miners.	Miners × months.	Coolies × months.	Materials. Gunpowder, lbs.	Match, yards.	Steel, lbs.	Iron, lbs.	Forges × months.	Transport. No. of waggons.	Running yard Railway in use at one time.	Do. laid and relaid.	Carpenters, &c., × months.	Coolies, × months.	Waggonmen, × months.	Bullocks, × months.
1st	47,787 {	0 318	2 6	75 225	150 1,350	200 360	5,000 25,000	7,500 75,000	375 3,375	6,000 54,000	4 30	0 56	9,600 + 400	9,600 2,400	40 10	600 75	200	750
2nd	90,000	450	8	325	2,600	720	50,000	160,000	6,500	104,000	64	92	10,000 + 500	8,500	34	300	384	1,600
3rd	90,000	450	8	250	2,000	720	40,000	132,500	5,000	80,000	48	92	10,000 + 500	7,500	30	250	384	1,600
	227,787				6,100	2,000	120,000	375,000	15,250	244,000	146	92	10,500	28,000	114	1,225	968	3,950

CAMP CHINNAMANOOR,
7th August 1867.

(Signed) J. G. RYVES, Captain, R. E.,
On Special duty.

No. 3.

Quantity of Masonry, &c., in the Escape.

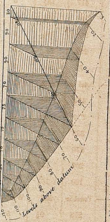
	Level above Datum.	Length at that Level.	Horizontal Slice. Length.	Breadth.	Height.	Cubic Feet.	Total.
Drop Walls.	$142\frac{1}{2}$	600					
			600	$9\frac{1}{8}$	5	27,375	
	$137\frac{1}{2}$	552					
			554	$9\frac{3}{8}$	5	$25,968\frac{3}{4}$	
	$132\frac{1}{2}$	508					
			512	$11\frac{1}{4}$	5	28,800	
	$127\frac{1}{2}$	463					
			468	13	5	30,420	
	$122\frac{1}{2}$	405					
			417	$14\frac{3}{4}$	5	$30,753\frac{3}{4}$	
	$117\frac{1}{2}$	340					
			358	$16\frac{1}{2}$	5	$29,445\frac{1}{2}$	
	$112\frac{1}{2}$	268					
			290	$18\frac{1}{4}$	5	$26,452\frac{1}{2}$	
	$107\frac{1}{2}$	160					
			202	20	5	20,200	
	$102\frac{1}{2}$	0					
			75	20	5	7,500	
	$97\frac{1}{2}$	0					
			Total in	Front	Wall	——	$226,915\frac{1}{2}$
	130	454					
			454	$9\frac{1}{8}$	5	$20,713\frac{3}{4}$	
	125	386					
			390	$9\frac{3}{8}$	5	$18,281\frac{1}{4}$	
	120	330					
			333	$11\frac{1}{4}$	5	$18,721\frac{1}{4}$	
	115	256					
			270	13	5	17,550	
	110	184					
			200	$14\frac{3}{4}$	5	14,750	
	105	45					
			100	$16\frac{1}{2}$	5	8,225	
	100	0					
			Total in	2nd	Wall	——	$98,241\frac{1}{4}$
	116	275					
			275	$9\frac{1}{8}$	5	$12,546\frac{7}{8}$	
	111	202					
			227	$9\frac{3}{8}$	5	$10,642\frac{5}{8}$	
	106	86					
			142	$11\frac{1}{4}$	5	$7,987\frac{1}{2}$	
	101	0					
			43	13	$3\frac{1}{2}$	$1,956\frac{1}{2}$	
	$97\frac{1}{2}$	—					
			Total in	Rear	Wall	——	$33,133\frac{1}{2}$

	Length.	Breadth.	Height.	Cubic Feet.	Total.
Wing Wall.	130	8 $6\frac{1}{2}$ 4	5 8 8	16,120	
	24	7 6 4	5 6 8	2,472	
	40	5 5 4	4 2 8	2,480	
	80	4 $3\frac{1}{2}$	3 6	2,640	
	50	$3\frac{1}{2}$	5	875	
		Total in Wing Wall		——	24,587
				Total Masonry...	$382,877\frac{1}{2}$ Cubic Feet.

Crests of Dropwalls—Best cut-stone work carefully fitted and in large masses......... 37,650
Faces of do. and front face of wing wall dressed beds and joints in Hydraulic cement 50,430
Remainder—Coursed rubble in mortar...... .... $294,797\frac{1}{2}$
Trench for foundation 84,000 cubic feet, out of rock.

No. 4.

Quantities of Earth and Puddle Work in the Bund.

Level above Datum.	Length at that Level.	Length of each vertical Slice.	Above 120′ Width Top.	Above 120′ Width Base.	Below 120′ Width Top.	Below 120′ Width Base.	+ Rear slope from 120′ level to the stone set wall and ground.	Puddle: of which Length at each Level.	Puddle: Length of each vertical Slice.	Puddle: Width at Base.	Puddle: Width at Top.
—10	0	267	$62\frac{1}{2}$	$272\frac{1}{2}$	$302\frac{1}{2}$	530		0	275	$106\frac{1}{4}$	
= 0	267	53	60	270	300	510		275	60	100	
10	320	60	$57\frac{1}{2}$	$267\frac{1}{2}$	$297\frac{1}{2}$	490		335	65	$93\frac{3}{4}$	
20	380	40	55	265	295	470		400	40	$87\frac{1}{2}$	
30	420	50	$52\frac{1}{2}$	$262\frac{1}{2}$	$292\frac{1}{2}$	450		440	60	$81\frac{1}{4}$	
40	470	95	50	260	290	430		500	100	75	
50	565	77	$47\frac{1}{2}$	$257\frac{1}{2}$	$287\frac{1}{2}$	410		600	75	$68\frac{3}{4}$	
60	642	83	45	255	285	390		675	75	$62\frac{1}{2}$	
70	725	75	$42\frac{1}{2}$	$252\frac{1}{2}$	$282\frac{1}{2}$	370		750	90	$56\frac{1}{4}$	
80	800	105	40	250	280	350		840	90	50	
90	905	55	$37\frac{1}{2}$	$247\frac{1}{2}$	$277\frac{1}{2}$	330		930	45	$43\frac{3}{4}$	
100	960	106	35	245	275	310		975	105	$37\frac{1}{2}$	
110	1,066	44	$32\frac{1}{2}$	$242\frac{1}{2}$	$272\frac{1}{2}$	290		1,080	40	$37\frac{1}{4}$	
120	1,110	52	30	240	270	270		1,120	50	25	
130	1,162	73	30	190	—	—		1,170	70	$18\frac{3}{4}$	
140	1,235	45	30	140	—	—		1,240	50	$12\frac{1}{2}$	
150	1,280	40	30	90	—	—		1,290	30	$6\frac{1}{4}$	
160	1,320	10	30	40	—	—		1,320		0	
162	1,330		30	30	—	—		—	—	—	

$(1{,}110\times138\frac{13}{24}+7{,}520\times281\frac{1}{4}+69{,}274)\times10$ ... =	30,485,300		
$(30\times70\frac{1}{4}+90\times2{,}531\frac{1}{4}+90\times4{,}916\frac{2}{3}+70\times4{,}916\frac{2}{3})$ ... =	993,542		
$\frac{13}{24}\times\left\{\begin{array}{l}75\times9{,}100+75\times6{,}100+70\times3{,}700+65\times1{,}900\\+60\times700\times40+100\end{array}\right\}$ ... =	849,603		
Total below the 120 feet level........	....	32,328,445	
$(1{,}110\times272\frac{1}{2}+7{,}520\times5)\times\frac{42}{2}$ ... =	7,141,575		
$\left.\begin{array}{l}(210\times56\frac{2}{3}+347\times50+33\frac{1}{3})\times10+40\times35\times2+45\times60\\\times12+73\times85\times22+52\times110\times32\end{array}\right\}$ ...	647,700		
Total above the 120 feet Level ...		7,789,275	
Puddle $=\frac{500}{48}\,3\times(17\times16l^1+16\times15l^2+{}^2\sqrt{c}\cdot—)+(l^1+l^2+\sqrt{c})$		40,117,720	
$=\frac{500}{48}(3\times166{,}170+1{,}290)=\frac{500}{48}\times499{,}800=$	Puddle...	5,206,250	= 192,824 C. yds.
	Earth...	34,911,470	=1,293,018 „
Stone wave screens—$(1{,}280+1{,}240+1{,}240)\times5\times10=$		188,000	= 6,963 „

No. 4.—*(Continued.)*

Estimate of Labor and Draft for the Earth, Puddle, and Stone Screen Work in the Bund.

Season.	Earth, Puddle, or Stone.	Quantity, Cubic yards, in the season.	Cubic yards per diem.	Months.	Excavating, Loading, Spreading, and Running. — Excavating.	Clearing debris of stones, &c.	Loading.	Unloading, spreading, and levelling.	Masons at 2× Coolies' hire.	Men.	Men × months.	Elephants × months.	Transport to Bund. — No. of wagons in use together.	Running yards Railway in use at one time.	Running yards Railway laid and re-laid.	Carpenters × months.	Coolies × months.	Wagon men × months.	Bullocks × months.	Boats' Crews × months.
1st	Earth ...	230,000	1,315	7	165	55	110	80	2×2	414	2,898	23	41		12,500	50	500	160	406	20
	Puddle ...	18,000	144	5	20	...	14	15	...	49	245	4½	6	6,000 + 2,000	3,000	12	120	40	55	4
	Puddle ...	32,000	640	2	90	...	64	70	3×2	230	460	8	25		6,000	24	240	40	94	8
2nd	Earth ...	300,000	1,500	8	187	63	125	90	2×2	469	3,752	30	47		15,000	60	600	200	592	51
	Puddle ...	20,000	140	5¾	19	...	14	14	...	47	264½	5	7	7,200 + 2,500	5,000	20	200	40	70	5
	Puddle ...	30,000	533	2¼	75	...	53	54	3×2	188	423	7½	24		6,000	24	240	40	106	8
3rd	Earth ...	335,000	1,675	8	209	70	140	100	2×2	523	4,184	33½	61		18,000	72	720	250	816	50
	Puddle ...	20,000	145	5½	20	...	14	12	...	46	253	5	8	7,750 + 3,250	6,000	24	240	40	82	6
	Puddle ...	27,000	432	2½	60	...	43	43	3×2	152	380	6¾	22		6,000	24	240	40	108	8
4th	Earth ...	335,000	1,675	8	209	70	140	96	2×2	519	4,152	33½	71		20,000	80	800	280	1,066	51
	Puddle ...	15,000	112½	5⅓	15	...	12	8	...	35	186⅔	3¾	7	8,250 + 3,750	6,000	24	240	40	69	5
	Puddle ...	25,000	375	2⅔	50	...	39	28	3×2	123	328	6¼	22		6,000	24	240	40	118	8
5th	Earth ...	83,018	415	8	51	17	35	30	4×2	141	1,128	8½	13	5,000	10,000	40	400	50	224	50
	Puddle ...	5,824	39	6	5	...	3	3	...	11	66	1½	...	......	....	...	...	...	...	6
	Stone ...	6,963	70	4	...	...	...	90	30×2	150	600	...	...	......	....	...	...	...	...	8
Total for Earth, Puddle, and Stone-wave-Screens...........											19,320	177	93	12,000	119,500	478	4,780	1,260	3,806	288

Estimate of cost of Plant, Tools, Machinery, and Buildings.

	RS.	RS.	RS.
Railway Material and Wagons.			
Rails, 57,500 yards of 2½" × ⅝" 9 lbs. per yard, 232 tons, at 175 Rupees ...	40,600		
Sleepers, 265,625 Running feet, at 30 Rupees per 100	79,688		
Nails, 23,125 dozens (2½ lbs. per dozen) at 3 dozens per Rupee ...	7,708		
		1,27,996	
Deduct for value after use—			
232 tons of bar iron, at 105 Rupees per ton ...	24,360		
17 tons of nails, at 120 Rupees per ton ...	2,040		
167,083 Running feet of sleepers, at 25 Rupees per 100.	44,246		
		70,646	
Net charge for Railway Material...	...	...	57,350
Wagons, 200, at 360 Rupees each ...	72,000		
For maintenance the several parts of 40 wagons, at Rupees 300 per set ...	12,000		
Do. Carpenters' and Smiths' hire ...	4,000		
		88,000	
Deduct for value after use—			
160 tons of cast-iron, at 90 Rupees per ton ...	14,400		
36 tons of wrought iron, at 120 Rupees per ton ...	4,320		
6,720 Cubic feet teak-wood, at ½ Rupee per cubic foot	3,360		
		22,080	
Net charge for Wagons...	...	...	65,920
Boats—sheet iron 10, complete with tackle, &c., at Rupees 3,500 ...	35,000		
Maintenance, at 5 per cent., for 5 years...	8,750		
		43,750	
Deduct for value after use, at 1,400 Rupees each...	...	14,000	
Net charge for Boats...	...	...	29,750
Tools for rock-cutting, tamping charging, and forges.	3,000		
Tools for earth and puddle and rail laying, at ¼ Rupee per man, month ...	6,830		
Tools for Carpenters', Smiths' &c., and Shop fittings.	4,500		
		14,330	
Deduct for value after use ...	...	5,530	
			8,800
Lifting and hauling Tackle. 6 one-ton Cranes at 600 Rs...	3,600		
3 two do. do. at 900 Rs..	2,700		
1 three do. do. at 1,350 Rs...	1,350		
8 single and double crabs at 200 Rs...	1,600		
5 five-ton do. at 500 Rs...	2,500		
Chain—(400 fms. ½ in., 200 fms. ¾ in.)—Rope (600fms. 1½ in., 400 fms. 3 in., 200 fms. 4½ in., 100 fms. 6 in.)	2,000		
Sundry— (posts, rollers, beams, &c.)... ...	750		
		14,000	
Deduct half for value after use ...	...	7,000	
Net charge for lifting and hauling Tackle	...	...	7,000
Syphons.—840 ft. 48in. pipe = 210 tons, at £6-10 per ton	13,650		
144 ,, ,, bends 36 ,, ,, £11 do.	3,960		
5 No. Sluice valves, complete, £88 each ...	4,400		
10 ,, filling cupolas do. £12 do. ...	1,200		
Freight and charges from England to Negapatam ...	11,700		
Carriage from Negapatam to the Perryaur.	10,400		
		45,310	
Deduct value of 260 tons cast iron pipes, at 100 Rs. per ton	...	26,000	
Net charge for Syphons...	...	...	19,310

Estimate of cost of Plant, Tools, Machinery, and Buildings.

	RS.	RS.	RS.
Pumps—1 centrifugal (24″ × 4½″) 10″ disch. pipe 24 feet and gearing	3,000		
2 double action Fire Engine pattern with 100 feet tubing	1,500		
Steam Engine 6 H.-P. portable	3,000		
		7,500	
Deduct half for value after use ...	...	3,750	
Net charge for Pumps and Steam Engine...	...	...	3,750
Total estimated cost of Plant, Tools, and Machinery..	...	...	1,91,880
Buildings.			
Officers' and Overseers' quarters 8,800 Sq. ft. covered.	10,500		
Workshops, Forges, Store-sheds, Sawpits, &c., ... 4,500 do. do...	3,450		
Barracks for one Company, Sappers, and 40 Police... ... 13,500 do. do...	13,500		
Hospitals. {1 for 45 Men, 1 ,, 10 Women, 1 ,, 25 Convicts} 8,000 do. do...	9,000		
Jail for 250 Convicts... ... 10,000 do. do...	8,750		
Lines for Maistries and skilled men... ... ... 3,000 do. do...	3,000		
Total for iron roofed buildings...	...	48,200	
Two Powder Magazines, each for 250 barrels... ...	...	3,000	
Deduct for value of materials, as follows:—			
62,666 Sq. ft. of corrugated iron at ⅛ Rupee ...	7,833		
19½ tons of cast iron at 75 ,, ...	1,462		
9½ ,, of wrought iron at 105 ,, ...	998		
1,950 C. ft. of teak and vengay at 1 ,, ...	1,950		
6,000 Sq. ft. of doors and windows at ⅓ ,, ...	2,000		
Total deductions...	...	14,243	
Net charge for buildings...	...	...	36,957
Warm clothing at 6 Annas per month for each man = ⅜ × 40,800 men, month	...	...	15,300
Total for Plant, Tools, Machinery, Buildings, and Warm clothing...	...	...	2,44,137

Of which to be charged to cutting ... ... Rupees 45,238
Do. ,, ,, Bund ... ... ,, 1,93,047
Do. ,, ,, Escape ... ... ,, 5,852

CAMP CHINNAMANOOR,
7th August 1867.

(Signed) J. G. RYVES, Captain, R. E.,
Superintending Engineer, on Special Duty.

A.

Method of working in the Bed of the River.—See Drawings on Sheet No. 6.

The working season in the Perryaar tract will consist of 200 days between the 1st of June and the 15th February, but for work in the bed of the river it would be limited to the period after the north-east monsoon freshes are over, and before the 15th February, besides, perhaps, twenty-five or thirty working days in August and September.

The first season's operations in the bed of the river will be commenced as soon as the north-east monsoon rains having ceased, the river discharge has fallen to about 100,000 cubic yards per hour.

During the previous months of this season the stone-dam (D) in rear will have been well advanced, and will now be at the 32 feet level, but with a clear opening of

45 feet wide left, through which the river will flow with a current of about 5 feet per second or 3⅓rd miles per hour.

The mean bed of the river at the site for the bund being* 6 feet, the water surface will now be 3 feet. This surface having been raised to + 12 feet by the temporary dam (d) across the 45 feet gap in the stone-dam, the earthen bund (B) will be raised (from boats in almost still-water) till its top is about 4 feet under water; and the current over its top therefore about half a mile per hour. The syphons, of which there will be four each 4 feet D^r will then be filled, and the temporary dam (*d*) having been removed, the water surface in front of B will fall to the + 8 feet level leaving the top† of the bund dry. The rear bund (b) will then be completed, and the water in the inclosed space pumped out.

* Captain Payne's B. M. on rock at the Moollyaar Junction being ≠0.

† Protected during the fall of the water surface by a casing of halved bamboos lashed together.

In this inclosed space the bottom layers of the puddle lining and of the earth bund will then be carried on, and at the same time the front and rear bunds (B) and (b) and the stone-dam (D) will be raised. When B and b have reached the + 20 feet and × 15 feet levels, two of the syphons will be raised to their corresponding level, and as soon as they are at work will be followed by the other two, and B and b made good across the spot formerly occupied by the syphons.

Thus the work will be gradually raised (except the corner XYZ in Plan which, for the present, must be left open for the water) in layers about 2 feet thick, the two bunds B and b being always 5 to 10 feet higher, and the stone-dam D about 15 feet higher than the work.

By the middle of February, when work will be stopped, the earth and puddle will have reached the + 25 feet level, and the stone-dam, now carried completely across the river, the + 42 feet level.

In this state the water in the bed of the river will be left till work can be commenced again in the next season, the rear bund (b^2) being protected from erosion by a casing of halved bamboos lashed together and loaded on the slopes with stone, the current over (b^2) when a big fresh of 1½ millions cubic yard per hour is flowing down the river, will be only a foot and a half per second or just over one mile per hour and over the crest of the stone dam the water's velocity would, according to my calculations, be about 6½ feet per second. The earth and puddle would not suffer to any serious extent under such a flood, and the stone-dam, though no doubt the stones in its rear slope, would be a good deal disturbed and many of them carried down to the bed of the river in rear, would not, in the few hours that a flood of this magnitude would last, lose any thing to signify in its height.

For nine days out of ten during the six months June to November the whole of stream will pass *through*, none of it *over*, the stone-dam (D), so that there will be nothing to prevent steady progress in its construction throughout the whole of the working season; and the earth and puddle work on the north flank of the river will also be carried on during all the two hundred days.

In the second season the operations in the bed of river would be as follows—(see 2nd Section Sheet No. 6.)

20th Aug.	River 150,000 cubic yards Surface + 45 feet.	Commence raising B earth from boats in practically still water.
30th Aug.	River 125,000 cubic yards Surface + 40 feet.	Top of B now at + 37 feet finish off with stone faced with clay, and at the same time fix the syphons in their places completely submerged.
5th Sept.	River 100,000 cubic yards Surface + 40½ in front + 34½ in rear.	Syphons now discharging 70,000 cubic yards per hour. 30,000 cubic yards passing over the stone top of B with a velocity of 1 mile per hour.

8th Sept.	River 87,500 cubic yards Surface + 40 in front. + $31\frac{1}{2}$ in rear.	The whole stream now taken by the syphons.

Pump out the water in the inclosed space below the $31\frac{1}{2}$ feet level, and go on with the work till the north-east monsoon freshes set in which will prevent any work being carried on in the river from about the middle of October till the end of November, when work will re-commence and go on till the 15th February.

The third section on Sheet No. 6 shows the state of the work as it is expected to be at the commencement and close of the third season.

In the fourth season the bund would be raised to the + 135 feet level throughout after the front of the work has reached the 110 feet level, the ordinary stream of the river will pass over the saddle E and the syphons be no longer required for the bund; they will then be transferred to the escape which (the foundations having been laid and wing-wall completed in the previous seasons) would in this season be raised to the + 115 feet level.

In the fifth season the bund and escape would be completed, and the stone screens built.

The whole might easily be done in four seasons, or indeed in three, if they happened to be moderately dry years; but it will be better to give the great mass of earth below the + 120 feet level time to settle before the top and the stone screens are finished off.

Of course the dates and surface levels given above as corresponding to certain states of the river are only approximations, the best I can make, and I believe, very near the truth, the surface levels depend on the permeability of the stone-dam, if the experience of the first season shows that the water surface on the up-stream side of the dam (D) corresponding to a certain discharge is much higher than I expect, an arched (dry stone) opening (or two, or three if necessary) will be left in the stone-dam at about the 30 feet level to ensure the fall of the river surface to a sufficiently low level on the cessation of freshets in the subsequent seasons.

B.

Table of the average Monthly and Annual Rain-fall at seven stations in the Districts, adjacent to the catchment basins of the Perryaar.

	Cochin, 13 years' average.	Trevandrum, 10 years' average.	Augustermully, 5 years' average.	Tencanshee, 10 years' average.	Trimungalum, 5 years' average.	Madura, 5 years' average.	Meyloor, 5 years' average.	Perryaar catchment estimated.
January ...	·34	·56	6·23	1·75	·13	·10	·70	1·52
February ...	·65	·39	2·28	·87	·13	·50	·72	·96
March ...	1·93	1·91	3·18	2·19	·56	1·12	1·19	1·80
April ...	5·30	5·48	7·41	6·36	3·75	2·92	2·70	4·53
May ...	13·34	8·87	30·66	2·92	2·09	2·82	2·59	9·82
June ...	28·05	11·84	28·64	3·82	·88	2·09	1·47	11·94
July ...	22·47	8·28	30·96	2·48	2·37	2·33	3·97	11·21
August ...	12·77	6·11	21·86	1·93	4·72	6·01	3·80	8·12
September ...	8·48	4·44	16·46	1·06	2·68	4·07	4·55	6·03
October ...	12·63	10·05	26·04	6·93	5·96	9·11	7·76	11·56
November ...	4·32	5·56	15·58	8·66	6·99	9·21	5·93	8·46
December ...	·88	1·52	9·72	2·61	1·32	2·21	2·21	3·03
The year ...	111·16	65·01	199·02	41·05	31·58	42·49	37·59	78·98

(Signed) J. G. RYVES, Captain, R. E.,
On Special duty

7th August 1867.

C. (Perryaar Project.)

Table showing the Discharge through the cutting and rise of the Lake surface, corresponding to different states of the river.

Period, days.	Discharge of river into the lake Million Cubic yards.	Outflow through the cutting Million Cubic yards.	Outflow over the escape Million Cubic yards.	Stored in lake above the 133 feet level.	Level of the lake surface.	Rate of inflow per hour, 1,000 cubic yards.	Rate of outflow through cutting, 1,000 cubic yards per hour.	
					133			
5	20	18·1	......	1·9	133½	167	151	
½	4	2·1	......	3·8	134	333	175	
½	6	2·3	......	7·5	135	500	192	
½	9	3	......	13·5	136½	750	250	
½	12	4	......	21·5	138⅜	1,000	333	
½	16	5·6	......	31·9	141	1,353	467	Big Fresh.
½	12	7·5	......	36·4	142 1/16	1,000	625	
1	10½	14·9	......	32	141	437	622	
2	15	23·8	......	23·2	138⅞	313	496	
3	18	26·2	......	15	136⅞	250	364	
6	30	37·4	......	7·6	135	208	260	
½	10	3·1	......	14·5	136¾	833	258	
½	18	4·9	......	27·6	140	1,500	408	
½	20	7·4	......	40·2	143	1,666	633	
½	25	10·2	6·2	48·7	145	2,083	850	
½	32	12·	16·3	52·4	145⅝	2,667	1,000	
½	40	13·2	23·2	56	146⅝	3,333	1,100	Extraordinary Fresh. Excess above cuttings safe rate of discharge = 17·1 million cubic yards.
1	50	24·7	35	46·3	144½	2,083	1,060	
1	25	20	10·6	40·7	143⅛	833	833	
3	40	48	·8	31·9	141	555	666	
4	40	47·8	......	24·1	139⅛	417	500	
5	36	44·7	......	15·4	137	300	375	
6	30	37·8	......	8·6	135	208	262	

Table showing the Discharge through the cutting and rise, &c.—*(Concluded.)*

Period, days.	Discharge of river into the lake Mn. Cubic yards.	Outflow through the cutting Mn. Cubic yards.	Outflow over the escape Mn. Cubic yards.	Stored in lake above the 133 feet level.	Level of the lake surface.	Rate of inflow per hour, 1,000 Cubic yards.	Rate of outflow through cutting, 1,000 Cubic yards per hour..	Remarks
$\frac{1}{4}$	9	1·5	......	15·1	$136\frac{11}{12}$	1,500	250	Great Flood. Excess above cuttings safe rate of discharge = 35·2 million cubic yards.
$\frac{1}{4}$	15	2·5	......	27·6	140	2,500	416	
$\frac{1}{4}$	$22\frac{1}{2}$	4	·4	45·7	$144\frac{1}{16}$	3,667	667	
$\frac{1}{4}$	30	6·4	9·4	59·8	$147\frac{1}{4}$	5,000	1,067	
$\frac{1}{4}$	40	8	22	69·8	$149\frac{3}{16}$	6,667	1,333	
$\frac{1}{4}$	45	9·4	31·6	73·8	150	7,500	1,567	
$\frac{1}{4}$	48	10	35·5	76·3	$150\frac{1}{2}$	8,000	1,667	
$\frac{1}{4}$	44	10·1	35·8	74·4	$150\frac{1}{8}$	7,333	1,683	
$\frac{1}{4}$	35	9·4	31·4	68·6	$149\frac{1}{10}$	5,833	1,567	
$\frac{1}{4}$	24	8·2	23·3	61·1	$147\frac{1}{2}$	4,000	1,367	
$\frac{1}{4}$	15	7	14·6	54·5	$146\frac{1}{8}$	2,500	1,167	
$\frac{1}{2}$	15	11·5	13·5	44·5	$143\frac{11}{12}$	1,250	958	
1	15	18·2	3·7	37·6	$142\frac{5}{16}$	625	758	
3	30	42	......	25·6	$139\frac{1}{2}$	417	583	
5	30	43·8	......	11·8	$136\frac{1}{12}$	250	365	
7	30	38·6	......	3·2	$133\frac{5}{6}$	179	230	
21	75	78·2	......	......	133	149	155	

7th August 1867.

(Signed) J. G. RYVES, Captain, R. E.,
On Special duty.

No. 1236.

Proceedings of the Madras Government
Under date the 4 ~~April~~ May 1871
Read the following.

From the Chief Engr. for Irrigation — N.E. No. 56 dated 28th Feby 1871.

Ordered that the Note by the Chief Engineer for Irrigation, with the papers accompanying it, be communicated to Mr. R Smith.

His Excellency the Governor in Council has noticed with satisfaction the care with which Captain Pennycuick has drawn up his report and the estimates connected with the head works of the Perryaur project, but

N.

Is it certain that Captain Pennycuick's suggestion is not a good one. A. J.

L. A. L.

His Excellency regrets that, whether from misconception on his part of the terms upon which this work was entrusted to him, or from his supposing that what he had seen in England warranted a departure from his instructions, he has worked out a scheme differing materially from that required. By so doing he has much reduced the value of his labours.

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The Government authorise the payment to Captain Pennycuick of £50, and the Controller of P.W. Accounts will be instructed to obtain and transmit to that Officer a bill for that amount, and he will report to what head of charge the cost of the bill should be debited.

W.R.C.

To
R Smith Esqr
Captn Pennycuick RE Sent to England
Contr of P.W. A. with the Bill
Chief Engr for Inf.
S. Engr & Dr

Dept 5th May 1871.

11-2-68

(15)

Rec. 20 [illegible] R. 22 [illegible]

C 14 Apl [illegible] R. 19th

…ovt of (1871) Madras.

PUBLIC WORKS.

R. Smith Esqre

140

…ted

…ed. Encl. 1

G. O., 4th May 1871. No. 1236

Nos. 71 & 72

Periyaur Project Head Works.

Asking orders on the [illegible]
to Chief Engr for Irrigation
on Capt. Pennycuick's de-
signs & Estimates for the
Periyaur Project Head
Works.